
Final Corrective Measures Study/ Feasibility Study

**Rocky Flats Environmental Technology Site
881 Hillside Area**

(Operable Unit No 1)



February 1995

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EXECUTIVE SUMMARY

This report documents the Corrective Measures Study/Feasibility Study (CMS/FS) performed for the 881 Hillside Area Operable Unit 1 (OU 1) of the Rocky Flats Environmental Technology Site (RFETS). The study was conducted in accordance with the requirements of the Rocky Flats Interagency Agreement (IAG) of January 1991. This agreement was signed between the U S Department of Energy (DOE), the U S Environmental Protection Agency (EPA), and the Colorado Department of Public Health and the Environment (CDPHE). The agreement specifies that the CMS/FS shall be conducted following appropriate Comprehensive Environmental Response Compensation and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) guidance.

The primary source of guidance used in the preparation of this report was EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, which outlines and describes the requirements of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Also used was EPA's *RCRA Corrective Action Plan* guidance, published in May 1994. In preparing this report, data on OU 1 were obtained from both the *Phase III RCRA Facility Investigation/Remedial Investigation (RFI/RI) Report* and the Rocky Flats Environmental Database System (RFEDS) directly. Where appropriate, recent soil gas survey data were used to enhance the conceptual model applied in the development of remedial action alternatives.

Following standard RCRA/CERCLA guidelines, results of the Phase III RFI/RI report were first examined to determine primary site contaminants and exposure pathways. Once these risk drivers were identified, remedial action objectives (RAOs) and preliminary remediation goals (PRGs) were formulated to address risks to human health and the environment. In the case of OU 1, the Environmental Evaluation (EE) portion of the Baseline Risk Assessment (BRA) did not identify any current or future risks to environmental receptors. Therefore, this report focuses on minimizing the risk to human receptors from contaminants identified in the RFI/RI report. The RAOs identified for OU 1 are listed below.

- 1) Prevent the inhalation of ingestion of and/or dermal contact with VOCs and inorganic contaminants in OU 1 groundwater that would result in a total excess cancer risk greater than 10^{-4} to 10^{-6} for carcinogens and/or a hazard index greater than or equal to 1 for non carcinogens
- 2) Prevent migration of contaminants from subsurface soils to groundwater that would result in groundwater contamination in excess of potential groundwater applicable or relevant and appropriate (ARARs) for OU 1 contaminants
- 3) Prevent migration of contaminants in OU 1 groundwater from adversely impacting surface water quality in Woman Creek

These RAOs were selected to address the primary risk exposure pathways identified for OU 1 the pathways associated with groundwater and indirectly subsurface soils Surface soils were also identified as a medium of concern in the OU 1 RFI/RI however this medium is being addressed under OU 2 Therefore PRGs for RAOs dealing with groundwater and subsurface soils were identified by examining both risk and applicable or relevant and appropriate requirement (ARAR) based values The exposure route of groundwater ingestion resulted in the highest potential risk to a future on site resident As a result the Colorado Basic Standards for Groundwater found in 5 Colorado Code of Regulations (CCR) 1002 8 3 11 5 and 3 11 6) were selected as appropriate PRGs for OU 1

After selecting appropriate PRGs for OU 1 remedial action alternatives were assembled that would provide various conceptual approaches for cleanup of the site The alternatives selected for detailed analysis are the following

- Alternative 0 No Action
- Alternative 1 Institutional Controls with the French Drain
- Alternative 2 Groundwater Pumping and Soil Vapor Extraction
- Alternative 3 Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement

- Alternative 4 Hot Air Injection with Mechanical Mixing
- Alternative 5 Soil Excavation with Groundwater Pumping

These alternatives were subjected to detailed analysis as required by RCRA and CERCLA guidelines and the NCP (40 Code of Federal Regulations 300.430). The standards and criteria used to analyze the alternatives are the following (with the exception of state and community acceptance which are analyzed later in the CMS/FS process)

- Overall protection of human health and the environment (including assessment of source control measures)
- Compliance with ARARs
- Long term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

The two threshold criteria, overall protection of human health and the environment and compliance with ARARs, are statutory requirements that must be satisfied by any alternative in order for it to be eligible for selection as the preferred remedial action alternative. The five primary balancing criteria of long term effectiveness and permanence, reduction in toxicity, mobility, and volume, short term effectiveness, implementability, and cost are used to evaluate major performance objectives for each alternative. The performance of each alternative in addressing each primary balancing criterion is evaluated and then compared across alternatives to assist in the selection of a preferred alternative.

The two modifying criteria state acceptance and community acceptance, evaluate the potential acceptance of the preferred alternative by regulatory agencies and the community. These last two criteria are not evaluated until after formal public comment on the CMS/FS and Corrective and Remedial Action Proposed Plan (PP) and are addressed in the final Corrective Action Decision/Record of Decision (CAD/ROD).

The results of the detailed analysis of alternatives are presented in this report. To support the analyses conducted herein, groundwater modeling and residual risk assessment calculations are included in Appendices B and C, respectively. Cost estimates are likewise included in Appendix A. A complete ARARs assessment is included in Appendix D. In general, these analyses show that most of the alternatives included in this analysis will meet groundwater PRGs at Woman Creek. The No Action alternative may not meet these goals at the French Drain, however, in terms of protecting human health and the environment, all of the alternatives presented result in residual risks of less than one in a million at Woman Creek. Only the No Action scenario presents a risk near one in ten thousand at the French Drain. Costs associated with the alternatives ranged from \$1.8 million for the No Action alternative, to over \$13 million for Alternative 5, Soil Excavation with Groundwater Pumping. Costs for the other alternatives were comparable and ranged from \$6 million to \$7.5 million.

Based on these results, *Alternative 0: No Action* would be the alternative of choice if performance and compliance are only monitored at Woman Creek. If, however, performance and compliance are monitored at the French Drain, then *Alternative 1: Institutional Controls with the French Drain* would most likely be the preferred alternative. Alternative 1 would also be a viable option if performance is monitored at Woman Creek as a contingency measure until more recent data are available concerning groundwater migration in OU 1 and how observed data compare to predicted data. Further discussion regarding the preferred alternative for OU 1 appears in the OU 1 PP.

TABLE OF CONTENTS

List of Figures	viii
List of Tables	viii
List of Acronyms	x
 EXECUTIVE SUMMARY	 1
 1 0 INTRODUCTION	 1 1
1 1 Purpose and Organization of Report	1 1
1 2 Site Background	1 6
1 3 Physical Characteristics	1 8
1 3 1 Geomorphology	1 8
1 3 2 Hydrogeology	1 11
1 4 Nature and Extent of Contamination	1 13
1 4 1 Volatile Organic Compounds	1 13
1 4 2 Metals	1 19
1 4 3 Semivolatile Organic Compounds	1 22
1 4 4 Radionuclides	1 23
1 4 5 Summary of Nature and Extent of Contamination	1 24
1 5 Fate and Transport of Contaminants	1 24
1 5 1 Volatile Organic Compounds	1 26
1 5 2 Metals	1 27
1 5 3 Semivolatile Organic Compounds	1 28
1 5 4 Radionuclides	1 28
1 5 5 Summary of Fate and Transport of Contaminants	1 29
1 6 Baseline Risk Assessment	1 29
1 6 1 Public Health Evaluation	1 29
1 6 2 Environmental Evaluation	1 32
1 6 3 Risk Summary	1 32
1 7 Interim Measures/Interim Remedial Actions	1 35

TABLE OF CONTENTS

(Continued)

2 0	IDENTIFICATION AND SELECTION OF TECHNOLOGIES AND REPRESENTATIVE PROCESS OPTIONS	2 1
2 1	Contaminants of Concern	2 1
2 2	Remedial Action Objectives	2 2
2 3	Preliminary Remediation Goals	2 3
2 3 1	Definition of Applicable or Relevant and Appropriate Requirements	2 5
2 3 2	Current Groundwater Classification	2 6
2 3 3	Selection of Groundwater PRGs	2 6
2 4	General Response Actions	2 7
2 4 1	Subsurface Soil General Response Actions	2 11
2 4 2	Groundwater General Response Actions	2 12
2 4 3	Volume and Area Estimates	2 13
2 5	Identification and Screening of Technologies and Process Options	2 16
2 5 1	Identification and Screening of Technologies and Process Options for Subsurface Soils	2 16
2 5 2	Identification and Screening of Technologies and Process Options for Groundwater	2 22
2 6	Evaluation and Selection of Representative Process Options	2 28
2 7	Existing IM/IRA Treatment System	2 36
3 0	DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES	3 1
3 1	Introduction	3 1
3 2	Remedial Action Alternatives	3 2
3 2 1	Alternative 0 No Action	3-4
3 2 2	Alternative 1 Institutional Controls with the French Drain	3-4
3 2 3	Alternative 2 Groundwater Pumping and Soil Vapor Extraction	3 6
3 2 4	Alternative 3 Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement	3 11

TABLE OF CONTENTS (Continued)

3 2 5	Alternative 4	Hot Air Injection with Mechanical Mixing	3 21
3 2 6	Alternative 5	Soil Excavation with Groundwater Pumping	3 24
4 0	DETAILED ANALYSIS OF ALTERNATIVES		4 1
4 1	Description of Evaluation Criteria		4 1
4 1 1	Overall Protection of Human Health and the Environment		4 1
4 1 2	Compliance with Applicable or Relevant and Appropriate Requirements		4 2
4 1 3	Long Term Effectiveness and Permanence		4 8
4 1 4	Reduction of Toxicity Mobility or Volume Through Treatment		4 10
4 1 5	Short Term Effectiveness		4 10
4 1 6	Implementability		4 10
4 1 7	Cost		4 11
4 1 8	State Acceptance		4 12
4 1 9	Community Acceptance		4 12
4 2	Background Analyses		4 12
4 2 1	Groundwater Monitoring		4 13
4 2 2	Groundwater Modeling		4 13
4 2 3	Residual Risk Assessment		4 16
4 3	Detailed Analysis of Alternatives		4 17
4 3 1	Alternative 0	No Action	4 21
4 3 2	Alternative 1	Institutional Controls with the French Drain	4 26
4 3 3	Alternative 2	Groundwater Pumping and Soil Vapor Extraction	4 34
4 3 4	Alternative 3	Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement	4 42
4 3 5	Alternative 4	Hot Air Injection with Mechanical Mixing	4 51
4 3 6	Alternative 5	Soil Excavation with Groundwater Pumping	4 59
4 4	Comparative Analysis of Alternatives		4 69
4 4 1	Overall Protection of Human Health and the Environment		4 69
4 4 2	Compliance with Applicable or Relevant and Appropriate Requirements		4 74
4 4 3	Long term Effectiveness and Permanence		4 76
4 4 4	Reduction of Toxicity Mobility, and Volume Through Treatment		4 78

TABLE OF CONTENTS (Continued)

4 4 5	Short term Effectiveness	4 79
4 4 6	Implementability	4 81
4 4 7	Cost	4 82
5 0	REFERENCES	5 1

List of Tables

1 1	Comparison of CERCLA Evaluation Criteria and RCRA Standards	1 5
1 2	Individual Hazardous Substance Site Descriptions	1 10
1 3	Contaminants Identified in the RFI/RI by Media	1 14
1 4	Summary of OU 1 Point Estimates of Carcinogenic Risk	1 33
1 5	Summary of OU 1 Point Estimates of Noncarcinogenic Risk	1 34
1 6	Summary of Primary IHSS Contaminants	1 36
2 1	Comparison of Potential Chemical Specific ARARs	2 8
2 2	Comparison of Existing Concentrations and Groundwater PRGs	2 10
3 1	Physical and Chemical Properties of the Primary VOCs in Groundwater	3 8
4 1	Predicted Peak Contaminant Concentrations and Human Health Risks	4-18
4 2	Summary of Detailed Analysis of Alternatives	4 70

List of Figures

1 1	CMS/FS Logic Flow Diagram	1 3
1 2	General Location of Rocky Flats Environmental Technology Site	1 7
1 3	Individual Hazardous Substance Site Locations	1 9
1 4	Total Target Volatiles Detected in Upper Hydrostratigraphic Unit Groundwater	1 17
1 5	Selenium and Vanadium Concentrations Detected in Upper Hydrostratigraphic Unit Groundwater	1 21
1 6	Potential Groundwater Migration Pathways	1 25
2 1	Potential Soil Excavation Area for IHSS 119 1	2 14
2 2	Potential Extent of Contamination at IHSS 119 1	2 15
2 3	Initial Screening of Technologies and Process Options for Subsurface Soils	2 19
2 4	Initial Screening of Technologies and Process Options for Groundwater	2 25
2 5	Evaluation of Process Options for Subsurface Soils	2 29
2 6	Evaluation of Process Options for Groundwater	2 31

TABLE OF CONTENTS
(Continued)

List of Figures
(Continued)

2 7	Conceptual View of Existing Building 891 Water Treatment	2 38
3 1	Development of Remedial Action Alternatives	3 3
3 2	Conceptual View of SVE System	3 9
3 3	Plan View for Alternative #3	3 12
3 4	Conceptual View of Radio Frequency Heating System	3 14
3 5	Conceptual View of Electrical Resistance Heating System	3 17
3 6	Conceptual View of Hot Air Injection System	3 23
3 7	Plan View for Alternative #4	3 25
3 8	Conceptual View of Excavation and Treatment Process	3 27
3 9	Plan View for Alternative #5	3 30
4 1	Summary of Remedial Action Alternative Costs	4 83

Appendices

Appendix A	Alternative Cost Estimates
Appendix B	Groundwater Modeling Results
Appendix C	Residual Risk Calculations
Appendix D	Potential Applicable or Relevant and Appropriate Requirements (ARARs)

LIST OF ACRONYMS

1 1 1 TCA	1 1 1 trichloroethane
ARAR	applicable or relevant and appropriate requirement
BRA	Baseline Risk Assessment
CAD	Corrective Action Decision
CAP	Corrective Action Plan
CCl ₄	carbon tetrachloride
CCR	Colorado Code of Regulations
CDOW	Colorado Department of Wildlife
CDPHE	Colorado Department of Public Health and the Environment
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	Code of Federal Regulations
CMS	Corrective Measures Study
COC	contaminant of concern
CRS	Colorado Revised Statutes
CWQCC	Colorado Water Quality Control Commission
DCE	dichloroethene
DNAPL	dense non aqueous phase liquid
DOE	U S Department of Energy
EE	Environmental Evaluation
EPA	U S Environmental Protection Agency
FS	Feasibility Study
GAC	granular activated carbon
gpd	gallons per day
gpm	gallons per minute
GRAs	general response actions
IAG	Inter Agency Agreement
IHSSs	Individual Hazardous Substance Sites
IM/IRA	Interim Measure/Interim Remedial Action
K _{oc}	organic carbon partition coefficient
K _{ow}	octanol water partition coefficient
LHSU	lower hydrostratigraphic unit
MAC	Maximum Allowable Concentration
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal

NAPL	non aqueous phase liquid
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NESHAP	National Emission Standards for Hazardous Air Pollutants
O&M	operation and maintenance
OSWER	Office of Solid Waste and Emergency Response
OU 1	Operable Unit 1
OU 2	Operable Unit 2
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	perchloroethene (or tetrachloroethene)
PHE	Public Health Evaluation
PP	Corrective and Remedial Action Proposed Plan
PRG	preliminary remediation goal
RACT	reasonably available control technology
RF	radio frequency
RAOs	remedial action objectives
RCRA	Resource Conservation and Recovery Act
RFEDS	Rocky Flats Environmental Database System
RFETS	Rocky Flats Environmental Technology Site
RFP	Rocky Flats Plant
RFI	RCRA Facility Investigation
RI	Remedial Investigation
ROD	Record of Decision
ROI	radius of influence
scfm	standard cubic feet per minute
SDWA	Safe Drinking Water Act
SID	South Interceptor Ditch
SWMU	Solid Waste Management Unit
SVE	soil vapor extraction
SVOC	semivolatile organic compound
TBC	to be considered
TCE	trichloroethene
TMV	toxicity mobility or volume
TSD	treatment storage and disposal facility
UHSU	upper hydrostratigraphic unit
USC	United States Code
UTL	upper tolerance limit
UV/H ₂ O ₂	ultraviolet/hydrogen peroxide
VOC	volatile organic compound

1 0 INTRODUCTION

This Corrective Measures Study/Feasibility Study (CMS/FS) report evaluates information necessary to support selection of the preferred remedial alternative(s) for Operable Unit 1 (OU 1) at the Rocky Flats Environmental Technology Site (RFETS). This report is part of a comprehensive program developed pursuant to the Rocky Flats Interagency Agreement (IAG) (January 1991) between the U S Department of Energy (DOE) the U S Environmental Protection Agency (EPA) and the Colorado Department of Public Health and the Environment (CDPHE). In accordance with the IAG this report addresses CMS provisions of the Resource Conservation and Recovery Act (RCRA) and FS provisions of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA).

1 1 Purpose and Organization of Report

The CERCLA Remedial Investigation (RI)/FS process provides the overall framework for this report as specified in the IAG IX D 1. Relevant RCRA specific CMS criteria are incorporated within this framework where appropriate. In general the CERCLA/RCRA process is intended to gather information sufficient to support an informed risk management decision regarding the most appropriate remedy for a given site. The process includes

- Characterization of the site's physical conditions
- Characterization of nature and extent of contamination
- Characterization of fate and transport of contamination
- Assessment of risk to human health and the environment
- Treatability testing if appropriate
- Development screening and detailed analysis of remedial alternatives
- Selection and implementation of remedial action(s)

This CMS/FS report documents the development screening and detailed analysis of remedial alternatives. Following CDPHE and EPA acceptance the results of this report along with information provided by previous reports will be summarized in a Corrective and Remedial Action Proposed Plan (PP). The PP is published for public review and comment public

comments will be responded to prior to selecting and implementing a remedy for OU 1. This CMS/FS follows EPA guidance established for general CMS and FS reports as outlined in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988a) and in the RCRA Corrective Action Plan guidance (EPA 1994). The guidances involve three phases shown graphically in Figure 1.1. The three phases are:

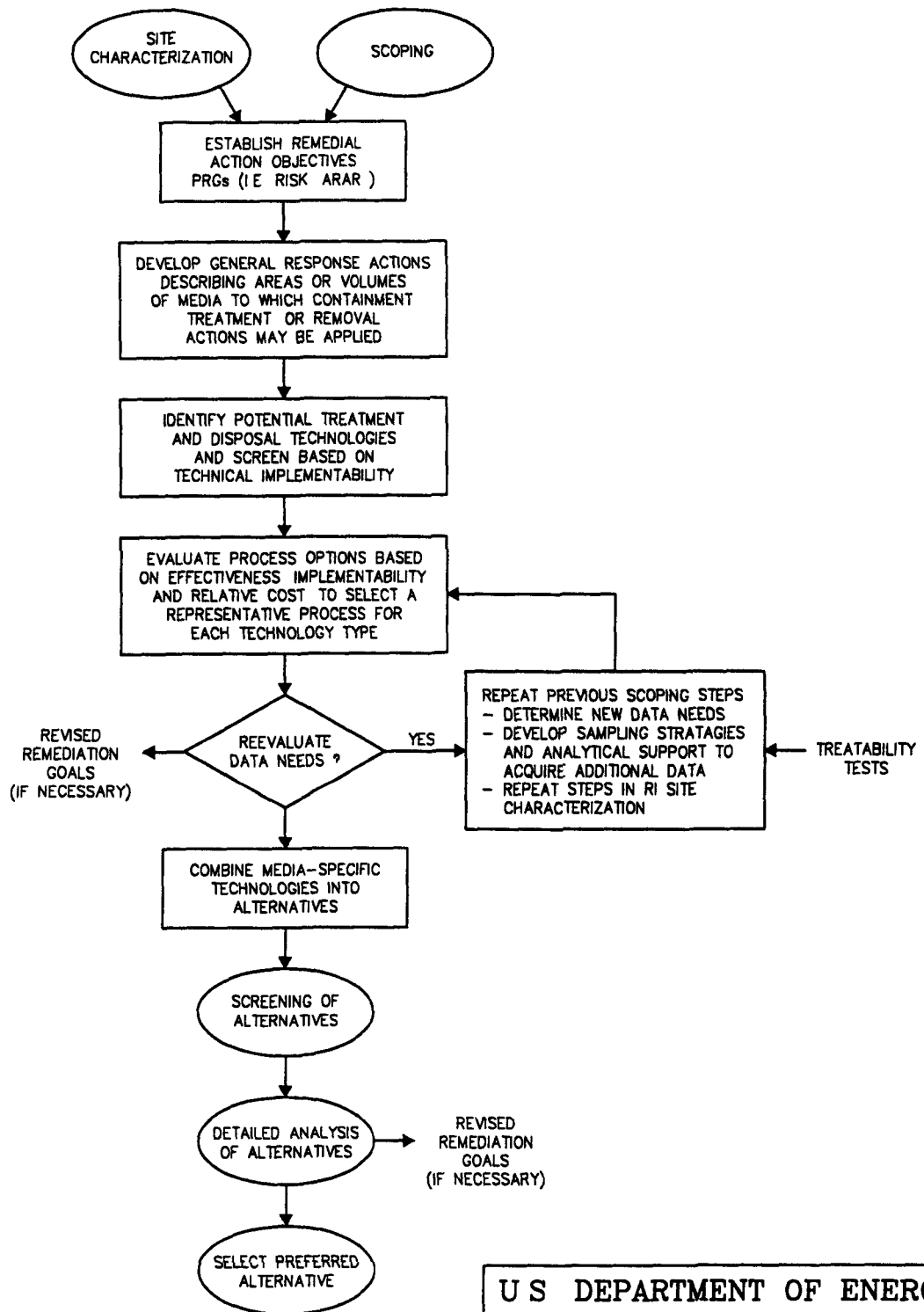
- Development of remediation goals and identification of process options
- Development and screening of alternatives
- Detailed analysis of alternatives

The development of remediation goals and identification of process options is included in this report as Section 2.0, "The Identification and Selection of Technologies and Representative Process Options." Representative remedial technologies capable of meeting remediation goals were selected for inclusion in remedial alternatives.

The Development of Alternatives phase is presented in Section 3.0 of this report. This phase identifies and combines potentially feasible remedial technologies to develop a range of remedial alternatives for OU 1. Specific components of this phase include:

- Development of media specific remedial action objectives (RAOs)
- Development of media specific general response actions (GRAs)
- Identification of volumes and/or areas of the media which require GRAs
- Identification and screening of technologies and process options for each GRA
- Evaluation of process options within each technology type to select a representative process option for the development of remedial action alternatives

The screening of alternatives is an optional phase that is conducted if the number of alternatives developed is too large to be reasonably carried forward to the detailed analysis. This screening is conducted on the basis of effectiveness, implementability, and cost. This screening was not conducted for OU 1.



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Golden Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

**CMS/FS Logic Flow
Diagram**

Figure 1-1

Section 4.0 presents the Detailed Analysis of Alternatives for those alternative that were carried forward from the screening phase described above. In this phase, the alternatives are further refined and analyzed in detail with respect to CERCLA criteria and RCRA standards that are provided in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and the RCRA Corrective Action Plan guidance (EPA 1994). The CERCLA criteria include

- Overall protection of human health and the environment
- Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)
- Long term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

In the detailed analysis, the first seven of these criteria are evaluated in two ways. First, each alternative is evaluated individually on its ability to satisfy each of the seven criteria. Second, the alternatives are subjected to a comparative analysis with the other alternatives. The State acceptance and community acceptance criteria are addressed in the Corrective Action Decision (CAD)/Record of Decision (ROD). Prior to the issuance of the CAD/ROD, the PP is submitted for public and State comment. Table 1.1 provides a comparison of CERCLA evaluation criteria and RCRA standards.

Because these CMS/FS phases—Development of Remediation Goals and Identification of Process Options, Development and Screening of Alternatives, and Detailed Analysis of Alternatives—are based on the results of previously conducted steps of the RCRA Facility Investigation (RFI)/RI, the following subsections briefly summarize the results of the RFI/RI. Section 1.2 discusses the Site Background. Section 1.3 discusses the Physical Characteristics of the site. Section 1.4 discusses the Nature and Extent.

Table 1-1
Comparison of CERCLA Evaluation Criteria and RCRA Standards

National Contingency Plan CERCLA Evaluation Criteria 40 CFR 300.430(e)(9)(iii)	RCRA Corrective Action Plan Standards OSWER Directive 9902.3-2A (May 1994)
Overall protection of human health and the environment	Protect human health and the environment
	Control the sources of releases ¹
Compliance with ARARs	Comply with any applicable standards for management of wastes
	Attain media cleanup standards set by the implementing agency
Long term effectiveness and permanence	Long term reliability and effectiveness
Reduction of toxicity, mobility, or volume through treatment	Reduction in the toxicity, mobility, or volume of wastes
Short term effectiveness	Short term effectiveness
Implementability	Implementability
Cost	Cost

¹ This criterion is addressed under the National Contingency Plan threshold criteria for Overall Protection of Human Health and the Environment. This criterion is also directly related to the Long Term Effectiveness and Permanence criteria.

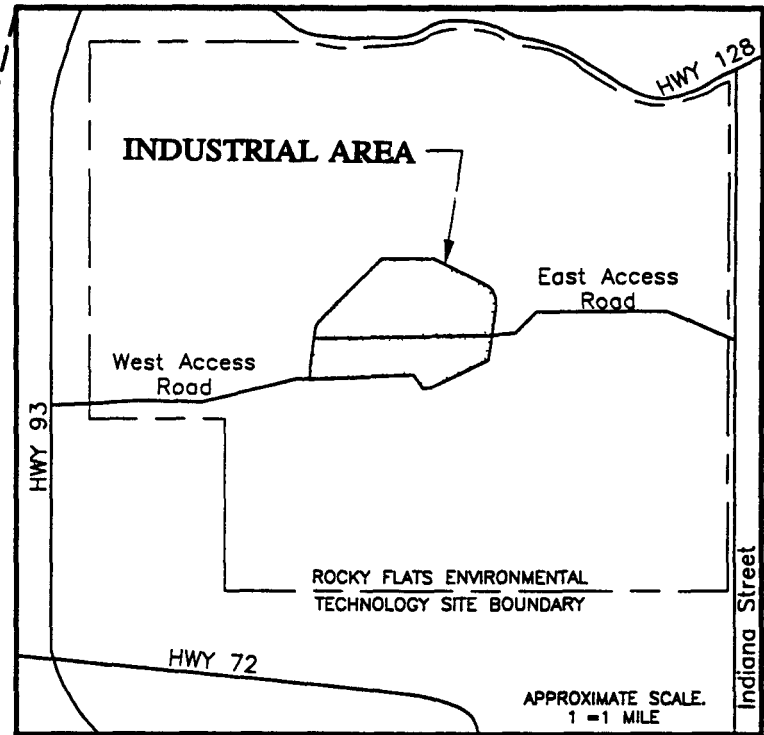
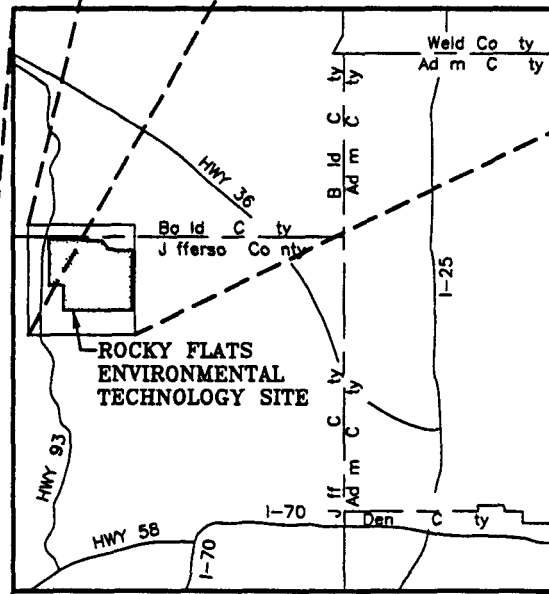
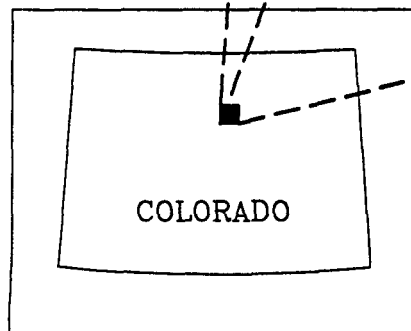
of Contamination Section 1 5 discusses the Fate and Transport of Contaminants, and Section 1 6 summarizes the Baseline Risk Assessment Section 1 7 discusses interim measures and interim remedial actions

1 2 Site Background

OU 1 also referred to as the 881 Hillside Area is located at the RFETS a DOE owned facility located approximately 16 miles northwest of downtown Denver Colorado (see Figure 1 2) RFETS occupies approximately 6 550 acres of federally owned land in northern Jefferson County Colorado The majority of the RFETS buildings are located within a 400 acre area referred to as the RFETS security area The 6 150 acres surrounding the security area are used as a buffer zone

Prior to 1994 the site was referred to as Rocky Flats Plant (RFP) Until 1992 RFP fabricated nuclear weapon components from plutonium uranium, beryllium and stainless steel Parts made at the plant were shipped elsewhere for assembly Support activities included chemical recovery and purification of recyclable transuranic radionuclides and research and development in metallurgy machining nondestructive testing, coatings remote engineering, chemistry and physics These activities generated radioactive hazardous and mixed waste On site storage and disposal of these wastes has contributed to hazardous and radioactive contamination in soils surface water and groundwater In July 1994 the plant was renamed to the RFETS to reflect a new mission of environmental restoration and the advancement of new and innovative technologies for waste management characterization and remediation

OU 1 is located in the southern portion of the security area on the hillside south of Building 881 and north of Woman Creek Historically Building 881 was used for enriched uranium operations and stainless steel manufacturing The laboratories in Building 881 also performed analyses of the materials generated in production The highest point in the immediate vicinity of OU 1 is Building 881 which is approximately 6 000 feet above mean sea level The lowest point is at Woman Creek about 5 830 feet above mean sea level Two surface drainages occur in the vicinity of OU 1 Woman Creek flows along the base of 881 Hillside south of OU 1 and the



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Golden Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

General Location of
Rocky Flats Environmental
Technology Site

Figure 1-2

South Interceptor Ditch (SID) crosses OU 1 between the security area and Woman Creek. A French Drain was constructed in 1992 across a significant portion of OU 1 above the SID to collect alluvial groundwater as an Interim Measure/Interim Remedial Action (IM/IRA).

OU 1 includes 11 sub areas that historical information suggested could exhibit potential contamination of soil, surface water, and/or groundwater. These sub-areas are referred to as Individual Hazardous Substance Sites (IHSSs). Figure 1.3 shows the locations of these IHSSs. Table 1.2 presents their descriptions. The RFI/RI was specifically designed to investigate the potential contamination at the IHSSs, as well as in the intervening areas of OU 1. The resulting data were used to characterize the physical and chemical conditions at OU 1.

1.3 Physical Characteristics

Information on the Physical Characteristics of OU 1 was obtained primarily from the *Phase III RCRA Facility Investigation/Remedial Investigation (RFI/RI) Report* (DOE 1994a). Where appropriate, more recent data from the Rocky Flats Environmental Database System (RFEDS) were used to update interpretations and to develop figures and contour maps presented herein. Two soil gas surveys conducted after publication of the Phase III RFI/RI report also supplemented current interpretations (DOE 1994b, DOE 1994c).

The physical characteristics of OU 1 which are relevant to the CMS/FS phases can be described considering geomorphologic and hydrogeologic features.

1.3.1 Geomorphology

The geomorphology at OU 1 reflects the interaction of several erosional and depositional processes which have produced gently rolling to moderately steep slopes on the Building 881 hillside. The terrain has been recontoured in several areas at various times during the construction of Building 881: the placement of fill and waste materials in several areas including the contractor yard and several IHSSs; the grading of roads at the site; the construction of the

Table 1 2
Individual Hazardous Substance Site Descriptions

IHSS Number	IHSS Name	Description
102	Oil Sludge Pit Site	Approximately 40 x 70 ft ² area located approximately 180 feet south of Building 881 where 30 to 50 drums of non radioactive oily sludge were emptied in the late 1950s The sludge was from the cleaning of two No 6 fuel oil tanks designated as IHSSs 105 1 and 105 2 and was backfilled when disposal operations ceased
103	Chemical Burial Site	Approximately 50 feet in diameter (2 000 ft ²) the pit is circular in shape and is located approximately 150 feet southeast of Building 881 on 1963 aerial photographs Area was reportedly used to bury unknown chemicals
104	Liquid Dumping Site	Reportedly a former (pre-1969) liquid waste disposal pond in area east of Building 881 no exact location or dimensions of pit location is uncertain due to poor quality of 1965 aerial photograph Approximate dimensions are 50 x 50 ft ²
105 1 105 2	Out-of-Service Fuel Oil Tank Sites	Located immediately south of Building 881 these were storage tanks for No 6 fuel oil Suspected leaks in 1972 Tanks closed in place through filling with asbestos-containing material and cement IHSS 107 the Hillside Oil Leak Site may have been caused by leakage from these tanks
106	Outfall Site	Overflow line from the sanitary sewer sump in Building 887 The outfall was used for discharge of untreated sanitary wastes in the 1950s and 1960s Due to concern about discharges from the outfall entering Woman Creek, several small retention ponds and an interceptor ditch were built in 1955 and 1979 respectively to divert the outfall water to Pond C 2
107	Hillside Oil Leak Site	Site of 1972 fuel oil spill from Building 881 foundation drain outfall A concrete skimming pond was built below the foundation drain outfall to contain the oil flowing from the foundation drain and an interceptor ditch was constructed to prevent oil-contaminated water from reaching Woman Creek
119 1 119 2	Multiple Solvent Spill Sites	Former drum storage areas east of Building 881 along the southern perimeter road IHSS 119 1 is the larger western drum and scrap metal storage area and appears to have contained mostly drums in the southern part of the IHSS and mostly scrap metal in the northern part, although material was moved around frequently as documented by aerial photographs IHSS 119 2 is the smaller eastern drum and scrap metal storage area and appears to have contained mostly scrap metal The drums contained unknown quantities and types of solvents and wastes The scrap metal may have been coated with residual oils and/or hydraulic coolants
130	Radioactive Site 800 Area #1	Area east of Building 881 Used between 1969 and 1972 to dispose of soil and asphalt contaminated with low levels of plutonium and uranium IHSS 130 is referred to as the Contaminated Soil Disposal Area East of Building 881 in the HRR to better match the history of waste disposal the site is included in the discussion of the 900 area at RFETS in that report IHSS 130 contains approximately 320 tons or 250 cubic yards which came from three sources 1) plutonium-contaminated soil and asphalt, placed in September of 1969 2) road asphalt and soil rad contaminated by leaking drum in transit and 3) 60 cu yds of plutonium contaminated soil removed from around the Building 774 process waste tanks in 1972
145	Sanitary Waste Line Leak	Six inch cast iron sanitary sewer line that originates at the Building 887 lift station and that leaked on the hillside south of Building 881 The line had conveyed sanitary wastes and low level radioactive laundry effluent to the sanitary treatment plant from about 1969 to 1973

SID and most recently the construction of the French Drain. The steepness of the hillside combined with various construction and excavation activities at OU 1, has resulted in mechanical failure manifested in widespread slumping of material (DOE 1994a). A number of wells on the hillside have been damaged by this slumping. These morphologic features influence surface and groundwater flow at the site.

Surface water at OU 1 occurs only during precipitation and snow melt events except in the interceptor ditch and the French Drain. Surface runoff generally flows toward Woman Creek, but likely infiltrates, evaporates, transpires, or encounters the interceptor ditch or French Drain before reaching Woman Creek. Surface water in the interceptor ditch is directed toward collection ponds for sampling prior to discharge. Surface water in the French Drain is directed to the water treatment system portion of the IM/IRA which removes organics and inorganics.

1.3.2 Hydrogeology

Groundwater hydrogeology has been a central component of the OU 1 RFI/RI. The most recent interpretations in the Phase III RFI/RI report represent a comprehensive evaluation of the OU hydrogeology based on eight years of investigation and monitoring. Groundwater at OU 1 is present in various geologic materials including the unconsolidated surficial material and the bedrock. A significant permeability contrast occurs at the base of a weathered zone which typically exists within the upper 5 to 25 ft of the bedrock. The weathered zone and overlying unconsolidated materials are generally 100 to 10,000 times more permeable than the underlying unweathered bedrock. This permeability contrast significantly limits the flux of groundwater into and through the unweathered bedrock (relative to the overlying materials) and consequently serves as the basis for defining two hydrostratigraphic units. The upper hydrostratigraphic unit (UHSU) consists of saturated portions of the Rocky Flats Alluvium, colluvial material, valley fill alluvium, and weathered bedrock; groundwater in these materials is typically unconfined. The lower hydrostratigraphic unit (LHSU) consists of saturated unweathered bedrock. Groundwater in the unweathered bedrock can be confined or unconfined.

Over most of the site groundwater flow in the UHSU occurs in disconnected northwest southeast trending channels that have been scoured into the bedrock surface. Groundwater in both the UHSU and LHSU flows from north to south toward the Woman Creek paleovalley. Bedrock highs and lithologic variability notably the presence of clay lenses act to retard the rate of groundwater flow. Flow has also been observed in glide planes bounding the slump blocks. Parts of OU 1 particularly in the eastern portion contain groundwater only in the spring months when water table elevations are typically highest. Groundwater levels across OU 1 are higher in spring than in the remainder of the year.

Recharge to the UHSU is minimal and occurs primarily through infiltration of precipitation. Infiltration rates range from 2 inches per hour for initial infiltration, to 0.5 inches per hour for final (saturated) infiltration. Localized sources of recharge include seepage from the Rocky Flats Alluvium to colluvial materials and former recharge from the Building 881 footing drain which has since been rerouted to the French Drain collection system. Flow from this drain averages 3.5 gallons per minute (gpm). Discharge occurs largely through evapotranspiration and discharge at boundaries such as seeps, Woman Creek, the SID, and the French Drain (DOE 1994a).

From aquifer test data the average linear flow velocity was estimated at 70 feet per year in the vicinity of IHSS 119, 1.8 feet per year in the vicinity of Building 881, and 180 feet per year within the Valley Fill Alluvium. The volume of UHSU groundwater at OU 1 was estimated at 5.8 acre feet in January 1992 and 5 acre feet in April 1992. The decrease from January to April is largely due to the rerouting of the foundation drain which was a source of recharge in the western part of OU 1 (DOE 1994a). Water levels screened in the UHSU rise annually in response to spring recharge and decline during the remainder of the year (DOE 1994a).

The overall range of hydraulic conductivity values estimated for UHSU materials was 3×10^{-3} to 2×10^{-6} cm/sec. The hydrologic data show a high degree of heterogeneity in the UHSU materials. The overall hydraulic conductivity for the LHSU ranges from 1.2×10^3 to 2.5×10^9 . Horizontal hydraulic conductivity values in bedrock appear to be 10 to 1,000 times greater than hydraulic conductivity values in the vertical direction.

Groundwater level data in the vicinity of the French Drain suggest that the system is effective in capturing UHSU groundwater originating from OU 1. For example, data from most of the UHSU monitoring wells downgradient (south) of the French Drain were dry in April 1993, a month typified by high water table elevations (DOE 1994a).

1.4 Nature and Extent of Contamination

This section summarizes the results of the nature and extent of contamination at OU 1 as presented in the Phase III RFI/RI report. Table 1.3 summarizes the contaminants identified in the Phase III RFI/RI report nature and extent assessment for the media of groundwater, surface soils, subsurface soils, surface water, and sediments. The investigative programs for these media were designed to characterize the nature and extent of contamination in the vicinity of the eleven IHSSs, as well as the intervening areas of the 881 Hillside Area. The resulting data indicate that many of the IHSSs are not sources of contamination. Furthermore, some sources occur outside of IHSS or even OU 1 boundaries. One of these situations involves surface soil contamination by americium and plutonium, which was shown in the Phase III RFI report to originate from within Operable Unit 2 (OU 2). Considering this scenario, all subsequent characterization and remedial activities related to surface soil contamination in OU 1 will be addressed under the OU 2 RFI/RI and CMS/FS programs.

1.4.1 Volatile Organic Compounds

Volatile organic compounds (VOCs) are present in subsurface soils and groundwater at OU 1. Chlorinated solvents occur sporadically in subsurface soils at the IHSSs. Sources for VOCs in groundwater appear to correlate with elevated concentrations in subsurface soils. Toluene occurs throughout OU 1 in subsurface soils at relatively low concentrations. The nature and extent of the detections suggest the source of the toluene may be laboratory or field introduced contamination—however, these hypotheses have not been confirmed.

Table 1 3
Contaminants Identified in the RFI/RI by Media

Contaminant	Ground Water	Surface Soil	Subsurface Soil ^b	Surface Water ^b	Sediment ^b
Volatile Organic Compounds					
Carbon Tetrachloride	X		X		
Chloroform	X		X		
1 1 Dichloroethane	X			X	
1 2 Dichloroethane	X		X	X	
1 1 Dichloroethene	X		X	X	
1 2 Dichloroethene	X			X	
cis 1 2 Dichloroethene	X				
Tetrachloroethene	X		X	X	
Toluene	X		X	X	X
Total Xylenes	X		X	X	
1 1 1 Trichloroethane	X		X	X	X
1 1 2 Trichloroethane	X				
Trichloroethene	X		X	X	
Metals					
Selenium	X				
Vanadium	X				
Radionuclides					
Americium		X	X	X	X
Uranium		X	X		
Plutonium		X	X	X	X
Polychlorinated Biphenyls (PCBs)					
AROCLOR 1248		X			
AROCLOR 1254		X			X

**Table 1-3
(Continued)**

Contaminant	Ground Water	Surface Soil	Subsurface Soil ^b	Surface Water ^b	Sediment ^b
Polynuclear Aromatic Hydrocarbons (PAHs)					
Acenaphthene		X	X		
Acenaphthylene		X			
Anthracene		X	X		
Benzo(a)anthracene		X	X		
Benzo(a)pyrene		X	X		
Benzo(b)fluoranthene		X	X		X
Benzo(ghi)perylene		X	X		
Benzo(k)fluoranthene		X	X		X
Chrysene		X	X		X
Dibenzo(a,h)anthracene		X			
Fluoranthene		X	X		X
Fluorene		X	X		
Indeno(1,2,3-cd)pyrene		X	X		
2-Methylnaphthalene			X		
Naphthalene		X	X		
Phenanthrene		X	X		X
Pyrene		X	X		X

^a Contaminants in surface soils are being addressed under OU 2

^b Contaminants in shaded media did not result in a cancer risk greater than 10^{-6} nor a hazard index greater than one

X Contaminant is a COC which has been detected in the medium

Groundwater chemistry data indicate VOCs occur in three general areas (DOE 1994a)

- South of Building 881
- IHSS 119 1 area
- Southeast of IHSS 119 2

Within these three areas (see Figure 1 4) concentration gradients and variations in analytes suggest that multiple release points are likely. Random isolated detections of relatively lower concentrations (0.11 to 6 ug/l total VOCs) occur in the intervening areas. Each of these areas is discussed in the following subsections.

Area South of Building 881

Groundwater in the area south of Building 881 exhibits relatively low concentrations of chlorinated solvents (ranging up to 130 $\mu\text{g}/\ell$). The spatial distribution of these detections is quite random, suggesting potential multiple point sources. Historical information corroborates this interpretation—the use or disposal of chlorinated compounds in discrete areas (including proximal IHSSs 145, 107, and 106) is not documented. The maximum VOC detection, 130 $\mu\text{g}/\ell$ of 1,1,1 trichloroethane (1,1,1 TCA), occurred at well 0187. Although this well is immediately down gradient of IHSS 145, a subsequent soil gas survey presented in the previous Phase I RFI/RI Report revealed no 1,1,1 TCA in the soil gas sample collected closest to well 0187.

Soil gas survey results reveal a high concentration of tetrachloroethene (PCE) in soil gas approximately 30 feet southwest of well 5287 (DOE 1994b). This detection is the second highest out of several hundred soil gas samples collected at OU 1 and suggests a potential source for PCE in subsurface soils. The detected concentration suggests the possible existence of residual or pooled dense non aqueous phase liquid (DNAPL). However, PCE was not detected in groundwater samples collected from wells located immediately down gradient of the soil gas detection (wells 5487/5387), suggesting that either the solvent release did not reach the water table (as a free phase wetting front) or that groundwater is not present at the location of

the release. These scenarios illustrate the sporadic nature and relatively low concentrations of VOCs in this area and suggest that multiple point sources exist south of Building 881.

IHSS 119.1 Area

Documented waste storage practices at this IHSS included the release of chlorinated solvents. Investigative activities confirm that these releases pose a continuing source for VOCs in groundwater. VOC concentrations are highest in the southwest portion of this IHSS, an area exhibiting drummed waste in historical aerial photographs. The Phase I soil gas survey identified several locations in this area which may represent discrete release points.

A comparison of the chemical suite detected in groundwater at several locations within the drum storage area revealed at least two distinct chemical mixtures. One is dominated by trichloroethene (TCE) and 1,1,1-TCA (well 0974) while the other is dominated by carbon tetrachloride (CCl₄) (well 1074).

Phase III RFI/RI results suggest VOCs occur in the form of DNAPLs in a zone directly beneath IHSS 119.1. An aqueous plume of TCE, TCA, and several other VOCs emanates from this DNAPL zone along the preferential groundwater flow pathway. This pathway is currently being intercepted by the French Drain.

The historical maximum concentration of VOCs in groundwater at OU 1 occurred at well 4787, although detections at this well have been characteristically sporadic and have involved relatively low concentrations. This probably reflects the effectiveness of the French Drain which was installed upgradient of well 4787. As discussed previously, most monitoring wells downgradient of the French Drain are dry.

Area Southeast of IHSS 119.2

Concentrations of chlorinated solvents detected in two closely spaced monitoring wells downgradient of IHSS 119.2 (wells 6286 and 6386) are attributed to potential VOC release areas.

at both IHSS 119 2 and upgradient of the operable unit. The occurrences of these VOCs in groundwater within the IHSS include one time detections of 9.3 $\mu\text{g}/\ell$ in UHSU well 34791 and 0.1 $\mu\text{g}/\ell$ LHSU well 4587. Chloroform detections occurred three times in well 4587 with a maximum detection of 18 $\mu\text{g}/\ell$.

Wells 6286 and 6386 exhibited VOC concentrations and are located in a drainage hydraulically downgradient from IHSS 119 2. Therefore a VOC release point is suspected in IHSS 119 2 and is shown on Figure 1.4 based on the location of suspected waste disposal features depicted on aerial photographs. The size of this suspected VOC release point is uncertain. It is speculated that contamination from the 903 Pad is also contributing to the VOCs detected in monitoring wells on the Hillside. The 903 Pad is upgradient of the impacted wells and is known to be a source for CCl_4 and other dissolved chlorinated solvents in groundwater.

The occurrence of chlorinated solvents in subsurface soils in this area is limited to a detection of 140 $\mu\text{g}/\text{kg}$ in borehole BH5887. The occurrence of VOCs in soil gas is limited to low levels of PCE and 1,1,1 TCA at one location within the IHSS. However the magnitude of the soil gas detections is several orders of magnitude less than those noted near Building 881 and IHSS 119 1 and are more representative of the local background around IHSS 119 2. Nevertheless as was the case at IHSS 119 1, the presence of a VOC release point within IHSS 119 2 boundaries is suspected based on the downgradient groundwater chemistry.

In summary VOC contamination occurs in subsurface soils, soil gas, and groundwater at OU 1. The nature and extent of VOCs in these media indicate that three general source areas exist: (1) the area south of Building 881, (2) IHSS 119 1, and (3) IHSS 119 2. Other IHSSs in OU 1 and the intervening areas, occasionally exhibit random low level concentrations which may reflect sources upgradient of OU 1.

1.4.2 Metals

Metal contaminants detected at OU 1 include vanadium and selenium. These metals were significantly elevated in groundwater but not in subsurface soils. Historical information does not indicate that these metals associated with wastes stored or disposed of at OU 1 but elevated

concentrations in areas where VOC wastes were stored. It is unlikely that these metals were leached from the soil by organic wastes disposed of at OU 1 since hydraulic oil and chlorinated solvents have poor chelation properties and are not strongly acidic or basic. Four areas have been identified at OU 1 with elevated selenium and/or vanadium as discussed below.

IHSS 119.1 Area

Multiple detections of selenium and vanadium were noted in monitoring wells located in the southwestern portion of IHSS 119.1 (Figure 1.5). Typically, the elevated metals were seen in association with VOCs. In particular, the highest metal concentration (2200 µg/l of Se) was detected in a well with one of the highest VOC concentrations anywhere at OU 1 (Well 1074). The maximum downgradient extent of selenium in groundwater at IHSS 119.1 appears to be in the vicinity of well 0487. The occurrence of vanadium is similar to selenium except that vanadium only occurs above background in UHSU wells.

Area South of Building 881

One detection of vanadium was noted at well 5387 at approximately six times the background level of 30 mg/l. This well exhibits concentrations of various chlorinated compounds in the 1 to 25 µg/l range. Several potential VOC source areas have been identified in the area south of Building 881; however, well 5387 is not particularly close to the suspected source areas. Nevertheless, it is conceivable that the vanadium present in groundwater at 5387 represents a plume originating from one of the VOC source areas previously discussed. The extent of vanadium concentrations above background near Building 881 appears to be limited to the immediate vicinity of well 5387.

Area East of IHSS 102

One detection of vanadium and three detections of selenium were noted above the background level in well 6986. No detections of VOCs have been noted at this well. It is unclear whether these detections represent contamination or naturally occurring levels as the maximum vanadium and selenium concentrations represent 126 percent and 194 percent of background respectively. Based on these relatively low levels, a contaminant source is not suspected in this area.

Southeast Corner of IHSS 130

Vanadium is the only contaminant detected at this location over background levels. A maximum of 403 $\mu\text{g}/\ell$ was detected at well 37191 which represents approximately five times the background level. Only exceedingly low levels of VOC contamination ($< 0.5 \mu\text{g}/\ell$) were found in association with the vanadium. The extent of vanadium and selenium contamination in the southeast corner of IHSS 130 appears to be limited to the immediate vicinity around well 37191.

In summary, metals detected at OU 1 were selenium and vanadium. These metals are found above background levels primarily in groundwater. Detections occurred in four areas: IHSS 199 1, IHSS 119 2, south of building 881, and east of IHSS 102.

1 4 3 Semivolatile Organic Compounds

The only semivolatile organic compounds (SVOCs) identified at OU 1 are PAHs and PCBs. PAHs occur over most of OU 1 but are limited to surface soils; concentrations tend to decrease with depth. In the Phase III RFI/RI, PAHs are generally not considered to be of OU 1 origin. However, asphalt and residues from a fire reportedly disposed in IHSS 130 (DOE 1994a) may be a source for PAHs. PAHs have also been detected in sediments. Several areas of OU 1 have been identified where PAHs appear more concentrated relative to the surrounding area. These areas, however, do not coincide with IHSS locations. Given this distribution, the sources for the PAHs at OU 1 are presumed to be general urban fallout including asphalt dust and larger

particles vehicle exhaust furnace exhaust and fires on plant site Similar distributions of PAHs occur at other OUs at RFETS corroborating this presumption

PCBs occur primarily in IHSSs 106 119 1 and 119 2 surface and subsurface soils generally lower concentrations were randomly detected in surrounding areas The contaminant release mechanism for PCBs is unknown One PCB detection has also been noted in sediments however the observation was at the western OU 1 boundary upgradient of the OU 1 source areas For this reason PCB occurrence is not considered to be of OU 1 origin

1 4 4 Radionuclides

Americium, plutonium, and uranium have been identified as OU 1 contaminants and are elevated in surface and subsurface soils In addition plutonium and americium are elevated in surface water and sediment The widespread plutonium and americium contamination in surface soil appears to be a result of deposition of wind disseminated plutonium/americium-contaminated dust originating from the 903 Pad Area Consistent with this hypothesis there is a general decrease in activities from east to west (ranging from a maximum of 22 7 pCi/g to 0 0076 pCi/g of plutonium and 4 15 pCi/g to 0 0129 pCi/g of americium) As mentioned earlier since the source of uranium contamination in surface soils is located in OU 2 this contamination will be addressed by the OU 2 RFI/RI and CMS/FS programs

In contrast to the wide spread plutonium/americium contamination localized hotspots of plutonium/americium or uranium are present at OU 1 These hotspots are postulated to reflect releases of radionuclide contaminated liquids stored in drums at OU 1, and have been addressed through an early removal action discussed in section 1 7 Areas within IHSS 130 contain low activities of americium and plutonium above the upper tolerance limit (UTL) in the shallow subsurface soils indicating a near surface widespread source Localized areas within the IHSS do contain low activities of plutonium and americium above the UTL at depth

Unlike plutonium and americium uranium contamination is not wide spread Instead uranium occurs at discrete locations in surface and subsurface soils at OU 1 In some areas uranium

233 234/uranium 238 ratios of approximately 1 to 2 suggest detections represent naturally occurring uranium. In other areas, uranium 233 234/uranium 238 ratios are higher, suggesting contamination by enriched uranium. As is the case for other radionuclides, surface soil contamination by uranium will be addressed by the OU 2 RFI/RI and CMS/FS programs.

Aside from areas within IHSS 130, the distribution of radionuclides at OU 1 appear random, rather than correlating with the IHSSs.

1.4.5 Summary of Nature and Extent of Contamination

In summary, contaminant groups represented in OU 1 media include VOCs, SVOCs, PCBs, metals, and radionuclides. One or more contaminants from these groups has impacted surface soils, subsurface soils, surface water, sediments, or groundwater. The distribution of these contaminants in these media is largely random, only IHSSs 119.1 and 119.2 and the area south of Building 881 exhibit clear evidence for consideration as sources. IHSSs 102, 130, and 106 also exhibit contamination, but the nature and distribution of detections in these areas is indicative of potential background contamination or off-site sources.

1.5 Fate and Transport of Contaminants

This section discusses potential mechanisms by which contaminants identified in the Phase III RFI/RI can migrate. Although several mechanisms are identified in the following sections, the groundwater medium is the most significant pathway. Figure 1.6 depicts potential groundwater migration pathways. Note that this figure does not represent the volume and velocity of groundwater flow in these pathways. Many areas of OU 1 are currently dry and remain dry throughout the year. The migration pathways presented in the figure present potential pathways assuming adequate groundwater is present.

1 5 1 Volatile Organic Compounds

The release mechanisms for VOCs at OU 1 are varied and include product leakage from stored drums possible leakage of dilute aqueous solutions of VOCs from pipelines and seepage of aqueous VOC solutions or product from impoundments and disposal pits In the area south of Building 881 a release mechanism may include leaking sanitary sewer lines (IHSS 145) In the western portion of OU 1 (IHSS 119 1) the release mechanism is most likely leakage from drums stored on the land surface

Once the contaminant has entered the subsurface the pathways for VOC migration include gravity driven wetting fronts of aqueous solutions and/or small volumes of product through the vadose zone to the water table In the case of product otherwise known as non aqueous phase liquid (NAPL) the density and relative immiscibility of chlorinated solvent can result in vertical migration of non aqueous phase contamination through the saturated zone This vertical non aqueous phase migration can be arrested if the geologic material retains the NAPL as residual or if impermeable material is encountered In either case dissolution to groundwater from residual or pooled NAPL can form an aqueous phase plume Precipitation and infiltration would also contribute to VOC migration as chlorinated solvents are dissolved and transported downward by infiltrating snowmelt and rainwater

Dissolved phase contaminants migrate in the direction of groundwater flow The rate of migration is dependent on the groundwater velocity and the affinity (or attraction) to the geologic materials In the case of OU 1 the migration rates of organic contaminants identified in the Phase III RFI/RI report are retarded relative to the groundwater velocity due primarily to relatively elevated attraction to the clayey materials Retardation is particularly significant for OU 1 contaminants with high octanol water partition coefficient (K_{ow}) values like CCl_4 (DOE 1994a)

At OU 1 UHSU groundwater flow patterns are controlled to a large degree by the topography of the bedrock surface Active channels in the bedrock are covered by unconsolidated material of varying thickness that is variably saturated Typically groundwater will flow towards the

axis of the bedrock channel and continue downgradient along the axis of the channel toward the south. The existing French Drain acts as a hydraulic barrier which intercepts contaminated groundwater in the western and central portions of OU 1 prior to reaching Woman Creek. In the eastern portion of OU 1 where the French Drain does not extend, the potential for contaminant migration to Woman Creek exists but has not been confirmed.

VOC contaminated groundwater may also discharge to surface water through seeps which have historically been observed at OU 1 (DOE 1994a). While VOCs in surface water have been previously detected in the SID, the more recently constructed French Drain has intercepted this pathway.

Other migration pathways for VOCs include volatilization of product into soil gas and subsequent migration of soil gas laterally and vertically away from the source area. VOCs can also partition out of contaminated groundwater into soil gas, move from soil gas into groundwater, or desorb from geologic material into soil gas. Considering the volatile nature of VOCs, they should not migrate in significant quantities through surface water or via wind transport of VOC contaminated surface soil.

1.5.2 Metals

The mechanism for the release of metal contaminants into the environment is less clear than for VOCs. Selenium and vanadium are undocumented RFETS contaminants that are presumed to be associated with the VOC wastes stored and disposed of at OU 1. It is unlikely that selenium and vanadium were leached from the soil by organic wastes disposed of at OU 1 since hydraulic oil and chlorinated solvents have poor chelation properties and are not strongly acidic or basic. Nevertheless, the potential for leaching of these metals exists. Alternatively, these constituents may be naturally occurring; however, there is insufficient data to support either conclusion. In either case, the primary migration pathway is as a dissolved phase contaminant plume in groundwater. This migration is the same pathway discussed in Section 1.5.1 for VOCs.

1 5 3 Semivolatile Organic Compounds

It is presumed that PAHs were deposited at OU 1 from fallout of combustion products or wind blown asphalt dust. Asphalt dust and larger particles may also have been transported and deposited by vehicles traversing OU 1 or by disposal of asphalt waste at OU 1.

Once in place, the dispersion mechanisms for PAHs include vertical migration by infiltrating surface water carrying dissolved PAHs or small particles with sorbed PAHs. The low solubility and high organic carbon partition coefficient (k_{oc}) values of PAHs limit mobilization of significant quantities in the dissolved form, and a direction of particulate matter through the porous media at OU 1 is unlikely to transport significant non aqueous PAH mass. Therefore, PAH transport via groundwater at OU 1 is not significant. Other transport mechanisms include surface water and wind transport of particulate, but soil and sediment data indicate these migration pathways are also insignificant for PAH transport.

Transport mechanisms for PCBs are similar to those for PAHs. PCBs are expected to be very immobile given the high k_{oc} values and the high carbon and clay content in surface soils at OU 1. Adsorption of PCBs at OU 1 is expected to be substantial on soils and clay particles (DOE 1994a).

1 5 4 Radionuclides

Transport mechanisms relevant to radionuclides are similar to PAHs. In particular, plutonium has a strong affinity for the solid phase and will not be readily mobilized by precipitation and infiltration. Plutonium is strongly adsorbed to clay particles and is expected to undergo strong cation exchange reactions due to its strong positive charge (DOE 1994a). The primary transport mechanism for plutonium is wind dispersion.

1 5 5 Summary of Fate and Transport of Contaminants

The primary mode of contaminant transport at OU 1 is through groundwater. The distribution of contaminants in groundwater illustrates the flow directions and pathways which trend south towards Woman Creek. These pathways are intercepted by the French Drain system prior to reaching Woman Creek except possibly in the far eastern portion of OU 1. Chemical data indicate that the pathways transport contaminants from three primary source areas: IHSS 119 1, 119 2, and south of building 881. Groundwater contamination outside of these pathways is random and generally involves relatively low concentrations.

1 6 Baseline Risk Assessment

The OU 1 Baseline Risk Assessment (BRA) consists of both a public health evaluation and an environmental evaluation. The primary purpose of each evaluation is to examine the current and future risks associated with contaminants identified during the analysis of the nature and extent of contamination. The following subsections summarize each evaluation and provide an overall summary of the risks associated with OU 1.

1 6 1 Public Health Evaluation

During the course of the Public Health Evaluation (PHE), site population and land use data were analyzed in order to devise several representative exposure scenarios (potentially exposed receptors) for assessing the risk to current and future human health from identified contaminants at the 881 Hillside Area. For each of these scenarios, pathways were analyzed which represented exposure routes from the source to potential receptors.

Pathway elements were examined relative to the results of the Phase III field investigation which indicated that contamination exists in the following media: groundwater, surface soils, subsurface soils, sediments, and surface waters. The contaminants identified in these areas included VOCs, PAHs, PCBs, inorganic contaminants, and radionuclides. The contaminant release mechanisms evaluated for OU 1 included leaching, volatilization, and resuspension of

particulates by wind. Potential transport media identified were surface water, groundwater, air, soil, and biota. The exposure route (the route of entry into the human body) for these media included ingestion, inhalation, and dermal contact. In accordance with the *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A)* (EPA 1989a), if any of the above mentioned pathway elements is missing, the projected receptor will not receive a chemical or radionuclide dosage and no excess risk will exist from that contaminant.

The OU 1 physical environment, including the French Drain and treatment system, was considered with information about the potentially exposed population, land use scenarios, and exposure pathways to form the conceptual site model. This was evaluated to identify complete pathways for credible and plausible exposure scenarios. The following list describes specific exposure scenarios and associated pathways that were selected for quantitative assessment.

- Current Off Site Resident
 - Inhalation of airborne particulates
 - Soil ingestion (following deposition of particulates on residential soil)
 - Dermal contact with soil (following airborne deposition of particulates)
 - Ingestion of homegrown vegetables/fruit (following surface disposition and uptake of particulates)
- Current On Site Worker
 - Inhalation of airborne particulates
 - Soil ingestion
 - Dermal contact with soil
 - Sediment ingestion
 - Dermal contact with sediment
 - Surface water ingestion
 - Dermal contact with surface water
- Future On Site Worker
 - Inhalation of VOCs in indoor air (office worker only) and outdoor air (construction worker only)
 - Inhalation of airborne particulates
 - Soil ingestion
 - Dermal contact with soil
 - Sediment ingestion (office worker only)

- Dermal contact with sediment (office worker only)
- Surface water ingestion (office worker only)
- Dermal contact with surface water (office worker only)
- Future On Site Ecological Researcher
 - Inhalation of airborne particulates
 - Soil ingestion
 - Dermal contact with soil
 - Sediment ingestion
 - Dermal contact with sediment
 - Surface water ingestion
 - Dermal contact with surface water
- Future On Site Resident
 - Inhalation of indoor VOCs from basement vapor
 - Inhalation of particulates
 - Soil ingestion
 - Dermal contact with soil
 - Sediment ingestion
 - Dermal contact with sediment
 - Surface water ingestion
 - Dermal contact with surface water
 - Ingestion of homegrown vegetables/fruit (following surface deposition of particulates and uptake)

The results of the BRA indicate that only the media of groundwater and surface soils present a risk greater than the acceptable risk range of 10^{-4} to 10^{-6} . The risk to a human receptor from exposure to groundwater contaminants of concern (COCs) is driven primarily by the exposure routes of ingestion and inhalation of volatiles. For a future on site resident this risk is on the order of 10^{-3} to 10^{-2} but applies only to exposures occurring directly at IHSS 119 1.

The risk to a human receptor from exposure to surface soil COCs is driven primarily by the exposure routes of ingestion of vegetables and inhalation of particulates. For a standard future on site resident this risk is on the order of 10^{-3} . It should be noted however that this risk is based on OU 1 sitewide average radionuclide concentrations. These average radionuclide concentrations include a few areas of high contaminant concentrations (i.e. hotspots) that are limited in extent and only exist within the boundaries of IHSSs 119 1 and 119 2. These hotspots

were remediated under an early removal action for OU 1 to measured (local) background concentrations. The risk to a future on site resident, excluding the hotspots, is much lower than calculations indicate when including the hotspots. Risk results are summarized in Tables 1.4 and 1.5.

1.6.2 Environmental Evaluation

As part of the overall BRA, an environmental evaluation (EE) was conducted to ascertain whether contamination resulting from RFETS activities in OU 1 may have impacted or could adversely impact ecological receptors in the vicinity. Ecological receptors are operationally defined as plants and animals other than humans and domesticated species.

COCs were selected for the EE based on a comparison of maximum concentrations of OU 1 contaminants to benchmark values. COCs identified in the EE include VOCs, PAHs, PCB, radionuclides, and selenium. The EE evaluated the impact that these COCs had on the following endpoints:

- Vegetative Community
- Small Mammal Community
- Mule Deer Population
- Toxic Exposure to Top Predators

The results of the EE indicate that the concentrations of VOCs in groundwater and PAHs and PCBs in soils are potentially toxic to ecological receptors; however, the restricted distribution of these contaminants limits the duration and frequency of contact with receptors and therefore limits exposures.

1.6.3 Risk Summary

As indicated by the PHE portion of the BRA, risks to human receptors at OU 1 are primarily associated with exposure to groundwater COCs. Although this medium is not available for

Table 1-4
Summary of OU 1 Point Estimates of Carcinogenic Risk

Scenario	Total Excess Cancer Risk	Dominant COC	Dominant Pathway
Current			
On Site Worker (Security Specialist)	1×10^{-4}	Plutonium 239 240	Inhalation of dust
Off Site Resident (Adult)	2×10^{-6}	Plutonium 239 240	Inhalation of dust
Standard Future			
Future On Site Worker (Office)	2×10^{-3}	Plutonium 239 240	Inhalation of dust
Future On Site Worker (Construction)	4×10^{-7}	1,1 Dichloroethene	Inhalation of volatiles
On Site Ecological Researcher	2×10^{-3}	Plutonium 239 240	Inhalation of dust
On Site Resident (Adult)	3×10^{-3}	Plutonium 239 240	Inhalation of dust
Other Future			
On Site Resident (Adult) (Sitewide With Groundwater)	6×10^{-3}	1,1 Dichloroethene	Ingestion of groundwater
On Site Resident (Adult) (Assuming Adequate Groundwater At Source)	7×10^{-2}	1,1 Dichloroethene	Ingestion of groundwater
On Site Resident (Adult) (Groundwater At Source With Public Water)	4×10^{-2}	Plutonium 239 240	Inhalation of dust
On Site Resident (Adult) (Without Source/Without Groundwater)	5×10^{-5}	Dibenzo(a,h)anthracene	Ingestion of vegetables

Plutonium concentrations are biased high by the presence of several hotspots which have been removed under an early removal action

Table 1 5
Summary of OU 1 Point Estimates of Noncarcinogenic Risk

Scenario	Total Hazard Index		Dominant COC	Dominant Pathway
	Child	Adult		
Current				
On Site Worker (Security Specialist)	N/A	8 x 10 ⁻⁵	Pyrene	Dermal contact with soil
Off Site Resident	1 x 10 ⁻⁷	6 x 10 ⁻⁸	Fluorene	Ingestion of vegetables
Standard Future				
Future On Site Worker (Office)	N/A	3 x 10 ⁻³	1 1 1 Trichloroethane	Inhalation of volatiles through foundation
Future On Site Worker (Construction)	N/A	1 x 10 ⁻⁴	1 1 1 Trichloroethane	Inhalation of volatiles during excavation
On Site Ecological Researcher	N/A	2 x 10 ⁻³	Pyrene	Dermal contact with soil
On Site Resident	2 x 10 ⁻²	5 x 10 ⁻³	1 1 1 Trichloroethane	Inhalation of volatiles through foundation
Other Future				
On Site Resident (Sitewide With Groundwater)	2 x 10 ⁺¹	9 x 10 ⁰	Carbon Tetrachloride	Ingestion of groundwater
On Site Resident (Assuming Adequate Groundwater At Source)	3 x 10 ⁺²	1 x 10 ⁺²	Carbon Tetrachloride	Ingestion of groundwater
On Site Resident (Groundwater At Source With Public Water)	3 x 10 ⁺¹	1 x 10 ⁺¹	Carbon Tetrachloride	Ingestion of groundwater
On Site Resident (Without Source/Without Groundwater)	7 x 10 ⁻³	3 x 10 ⁻³	Fluorene	Ingestion of vegetables

current residential use this scenario presents the highest and only unacceptable risk per the NCP guideline of 10^{-4} to 10^{-6} Environmental risks currently have not been identified by the Phase III RFI/RI and therefore do not warrant further examination

OU 1 risks are a result of widespread contamination found in low concentrations and in various media throughout the site The Phase III RFI/RI results indicate that for the most part individual IHSSs cannot be associated directly with any one contaminant group or area Table 1 6 lists the primary contaminants present at each IHSS IHSS 119 1 119 2 and the area south of Building 881 represent the primary sources for contaminant migration

1 7 Interim Measures/Interim Remedial Actions

The IM/IRA that was completed for OU 1 consists of a French Drain designed to collect contaminated alluvial groundwater from the operable unit and to prevent further downgradient migration of contaminants The IM/IRA included a geotechnical investigation that was performed in order to evaluate the site characteristics along the proposed French Drain alignment (EG&G 1990) Construction of the French Drain began in November 1991 and was completed in April 1992 The water treatment plant located in Building 891 is part of the IM/IRA and will be converted to sitewide uses Hereinafter this plant is referred to as the Building 891 water treatment plant

The French Drain was constructed by excavating a trench approximately 1 435 feet in length (DOE 1994a) The trench was keyed into bedrock material that exhibited a hydraulic conductivity on the order of 1×10^{-6} cm/sec A permeable membrane was placed on the upgradient side of the drain and an impermeable polyvinyl chloride membrane was placed on the downgradient side of the drain A perforated pipe was placed along the drain to collect groundwater and the drain was backfilled with gravel and then soil Currently groundwater collected from the drain is fed into an ultraviolet and hydrogen peroxide (UV/H₂O₂) treatment unit for treatment of organic compounds Inorganic contaminants are removed via a series of ion exchange columns

Table 1-6
Summary of Primary IHSS Contaminants

IHSS Number	Primary Contaminants^a	Disposition
102	Groundwater contaminated with PCE and TCE	Considered in Building 881 Area
103	Possible groundwater and subsurface soils contaminated with low levels of PCE and TCE	Considered in Building 881 Area
104	Potential toluene in subsurface and groundwater wide array of PAHs	Not identified as a source no action required
105 1 & 105 2	Low levels of VOCs in groundwater PCE detected below detection limit potential solvent contamination in soils at north end	Considered in Building 881 Area although not identified as a source
106	Groundwater contaminated with chlorinated solvents potential solvent contamination in soils at north end	Considered in Building 881 Area although not identified as a source
107	Groundwater contaminated with chlorinated solvents	Considered in Building 881 Area although not identified as a source
119 1 & 119 2	Groundwater contaminated with chlorinated solvents and selenium possible DNAPL sources in subsurface radionuclide hotspots	Considered under IHSS 119 1 and Area East of 119 2
130	Radionuclide-contaminated soil and asphalt PAHs in subsurface soils	No risk pathway for rads and PAHs in subsurface soils no action required Not identified as a source of VOCs
145	Groundwater contaminated with chlorinated solvents potential low level rad contamination	Considered in Building 881 Area although not identified as a source

Radionuclide and PAH contamination in near surface soils is being addressed under OU 2

2 0 IDENTIFICATION AND SELECTION OF TECHNOLOGIES AND REPRESENTATIVE PROCESS OPTIONS

This section summarizes the results of the identification and selection of technologies and representative process options used in the development of remedial action alternatives for OU 1. Technologies and representative process options were identified, screened, evaluated, and then selected for further evaluation in the CMS/FS. This sequential task is outlined and discussed in both CERCLA RI/FS and RCRA CAP guidance. Briefly summarized EPA guidance identifies the following elements for selecting representative process options:

- Identify list of contaminants of concern
- Develop media specific RAOs
- Identify Preliminary Remediation Goals (PRGs)
- Develop media specific GRAs
- Identify volumes and/or areas of the media for GRAs
- Identify and screen technologies and process options applicable to each GRA
- Evaluate process options within each technology type to select a representative option for developing remedial action alternatives

2 1 Contaminants of Concern

The list of contaminants identified in the Phase III RFI/RI nature and extent assessment is summarized in Section 1 0 of this report. Potential contaminants identified early in the RFI/RI process were subjected to a multi level screening process that resulted in public health and ecological COCs for inclusion in the PHE and EE. The screening process shortened the list of potential contaminants that are also risk contributors. Contaminants that survived the risk based screening process are designated as COCs in the BRA.

The COCs screened in the PHE and EE were

- carbon tetrachloride
- 1 1 dichloroethene
- tetrachloroethene
- 1 1 1 trichloroethane
- trichloroethene
- toluene
- selenium
- PAHs
- PCBs
- americium
- plutonium
- uranium

The screening of COCs for significant risk to ecological receptors found that none of these contaminants contribute a significant risk to ecological receptors. In addition, adverse impacts to the environmental receptors have not been identified in the EE. Therefore COCs for ecological receptors are not further evaluated in this report.

The screening of the contaminants for human health risk found some contaminants do contribute a significant risk. The risks associated with some of the contaminants in groundwater exceed 10^{-4} for future residential receptors within the OU 1 boundaries. The following groundwater COCs are identified at IHSS 119 1:

- carbon tetrachloride
- 1 1 dichloroethene
- tetrachloroethene
- 1 1 1 trichloroethane
- selenium

These COCs only represent a portion of the contaminants identified at OU 1. The complete list presented in Section 1.0 will be examined relative to remedial action alternatives.

2.2 Remedial Action Objectives

RAOs were formulated using appropriate regulatory guidelines (i.e. EPA RI/FS and CAP guidances and the NCP) and by examining the relevant COCs and their associated exposure.

pathways In general RAOs are contaminant and medium specific goals for protecting human health and the environment In developing appropriate RAOs guidance states that objectives should be as specific as possible but not so specific that the range of alternatives that can be developed is unduly limited In order to quantify RAOs, PRGs were developed that provide an identification of what an acceptable contaminant level or range of levels would be for each exposure route of concern Note that a risk range is presented for those RAOs that specify a protectiveness level The range is necessary since PRGs are typically estimated based on a risk level of 1×10^{-6} for each contaminant Depending on the number of contaminants present the summed residual risk may therefore be slightly higher than 1×10^{-6} hence the defined acceptable range

Review of the groundwater COCs and the associated exposure pathways resulted in the following RAOs

- 1) Prevent the inhalation of ingestion of and/or dermal contact with VOCs and inorganic contaminants in OU 1 groundwater that would result in a total excess cancer risk greater than 10^{-4} to 10^{-6} for carcinogens and/or a hazard index greater than or equal to 1 for non carcinogens
- 2) Prevent migration of contaminants from subsurface soils to groundwater that would result in groundwater contamination in excess of potential groundwater ARARs for OU 1 contaminants
- 3) Prevent migration of contaminants in OU 1 groundwater from adversely impacting surface water quality in Woman Creek

These RAOs have been used to determine the area or areas within OU 1 requiring remedial action evaluation The RAOs have been further quantified through the development of PRGs

2.3 Preliminary Remediation Goals

This section presents the sources of information used for identifying appropriate PRGs for OU 1 PRGs are generally identified through use of readily available information such as chemical specific ARARs or other reliable information (EPA 1990a) Where ARARs or to be

considered (TBC) criteria are not available, PRGs are developed on the basis of a 10^{-6} point of departure risk for each chemical within a given medium. This also applies when ARARs are not considered sufficiently protective because of the presence of multiple contaminants or multiple pathways of exposure.

Note that PRGs developed at this stage are considered initial goals which may be modified through the course of the CMS/FS. Final remediation goals are not selected until the remedy selection phase of the CMS/FS according to the NCP requirements. The ARARs presented in Section 2.3 as well as the risk based PRGs can be considered initial cleanup goals; however, exact criteria for final remediation will be selected as the CERCLA process proceeds. Either set of criteria could be used, a combination could be used, or revised PRGs could be used if necessary. The decision as to whether or not revised PRGs are required is based on the criteria described in the preamble to the NCP (55 Federal Register [FR] 8717, March 8, 1990) which states that:

Preliminary remediation goals may be revised based on the consideration of appropriate factors including but not limited to exposure factors, uncertainty factors, and technical factors.

Referring to the detailed analysis of alternatives, the preamble also states that:

The final selection of the appropriate risk level is made when the remedy is selected based on the balancing criteria.

Generally, chemical specific ARARs take precedence over risk based PRGs; however, as noted above, final cleanup goals will depend on a variety of factors and will be agreed upon by the participating agencies (i.e., DOE, EPA, and CDPHE).

2 3 1 Definition of Applicable or Relevant and Appropriate Requirements

CERCLA Section 121(d)(2) provides a statutory basis for determining ARARs in a remedial action context. Concerning hazardous substances, pollutants, or contaminants that will remain on site:

If any standard, requirement, criteria, or limitation under any federal environmental law or any [more stringent] promulgated standard, requirement, criteria, or limitation under a state environmental or facility siting law is legally applicable to the hazardous substance concerned or is relevant and appropriate under the circumstances of the release or threatened release of such hazardous substance, pollutant, or contaminant, the remedial action shall require, at the completion of the remedial action, a level or standard of control for such hazardous substance, pollutant, or contaminant which at least attains such legally applicable or relevant and appropriate standard, requirement, criteria, or limitation. [42 United States Code (USC) § 9621(d)(2)]

where applicable requirements are those:

cleanup standards, standards of control, or other substantive environmental protection requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.

According to the NCP and the *CERCLA Compliance with Other Laws Manual* (EPA 1988b):

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site so that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.

Potential chemical specific ARARs have been identified in accordance with CERCLA guidance and the requirements of the NCP [see Title 40 Code of Federal Regulations (CFR) Part 300 Subsection 430(e)(2)(i)] Chemical specific requirements under a variety of Federal and state laws were reviewed to identify potential groundwater chemical specific ARARs

The NCP also requires an evaluation of current or potential uses of the groundwater as part of the determination of ARARs (40 CFR 300.430(e)(2)(i)(A)(3)) The groundwater classification at RFETS is discussed in the context of current and potential future uses of groundwater beneath OU 1

2.3.2 Current Groundwater Classification

The Colorado Water Quality Control Commission (CWQCC) designated the Quaternary and Rocky Flats Aquifers beneath the RFETS as domestic use quality agricultural use quality and surface water protection according to 3.12.7 of 5 Colorado Code of Regulations (CCR) 1002.8 The intent of these classifications is to protect specified groundwater from uncontrolled degradation and thereby protect existing and future uses of groundwater (5 CCR 1002.8 Subsection 3.11.9)

2.3.3 Selection of Groundwater PRGs

Various laws and regulations have been reviewed for general applicability in the search for potential groundwater cleanup standards at the OU 1 site The laws and regulations reviewed are

- Safe Drinking Water Act and the implementing Federal and State programs (40 CFR 140.141 and Colorado Revised Statutes (CRS) 25-1-107, 25-1-109, 25-1-114, and 24-4-104 through 105 including the State drinking water regulations
- Resource Conservation and Recovery Act and the State's implementing regulations (6 CCR 1007.3) and
- State Water Quality Control Act and the groundwater quality implementing regulations

(5 CCR 1002 8 3 11 0 and 3 12 0)

Table 2 1 identifies the numerical standards associated with each of the regulations related to quality of groundwater. Further review of each set of related groundwater regulations and the guidance established specific to the NCP regulations (40 CFR 300 430 (d)(2)(i)) refined this list of potential numerical standards. The most stringent numeric standards that have been promulgated and which meet the definition of general applicability in 40 CFR 300 400(g)(4) are the State Groundwater Standards in 5 CCR 1002 8 3 11 5. The maximum contaminant levels (MCLs) established in the State and Federal drinking water program are less stringent than the State Basic Standards for Groundwater. The Resource Conservation and Recovery Act groundwater protection standards do not include MCLs for most of the contaminants of concern at OU 1. Therefore the State Basic Standards for Groundwater were selected as the potential chemical specific ARARs. The numeric site-specific standards in 5 CCR 1002 8 3 12 0 are to be considered in the evaluation of remediation alternatives for OU 1.

The statewide standards for groundwater are identified as the initial PRGs for OU 1 and are presented in Table 2 2.

2 4 General Response Actions

GRAs are general response strategies that are designed to satisfy remedial action objectives. Examples of GRAs include treatment, containment, excavation, and extraction. GRAs are medium specific and therefore a list of GRAs are developed for each medium of concern. GRAs were identified for the groundwater medium at OU 1 because contaminants of concern and PRGs are focused on this medium. Since subsurface soils are a potential continual source of groundwater contamination, subsurface soil GRAs were also developed which seek to protect groundwater from possible residual contamination.

Table 2 1
Comparison of Potential Chemical Specific ARARs
($\mu\text{g/l}$)

Chemical	Federal MCL ¹	Federal MCLG ²	State RCRA Groundwater Protection Standards ³	State MCL ⁴	State Basic Standards for Groundwater ⁵	State-Specific Standards for Groundwater ⁶			CDPHE PQL ⁷
						Table 1 Human Health	Table 3 Agriculture	Table 5 Chronic	
Volatile Organic Compounds									
Carbon Tetrachloride	5	0	—	5	0.3	—	—	—	1
Chloroform	<100	—	—	<100	6	—	—	0.19	1
1,1-Dichloroethane	—	—	—	—	—	—	—	—	—
1,2-Dichloroethane	5	0	—	5	0.4	—	—	—	1
1,1,1-Trichloroethene	7	7	—	7	7	—	—	—	1
1,2-Dichloroethene	—	—	—	—	—	—	—	—	1
cis-1,2-Dichloroethene	70	70	—	70	70*	—	—	—	1
Tetrachloroethene	5	0	—	5	5	—	—	0.8	1
Toluene	1,000	1,000	—	1,000	1,000	—	—	—	1
Total Xylenes	10,000	10,000	—	10,000	10,000*	—	—	—	1
1,1,1-Trichloroethane	200	200	—	200	200	—	—	—	1
1,1,2-Trichloroethane	5	3	—	5	3	—	—	0.6	1
Trichloroethene	5	0	—	5	5	—	—	—	1
Semi-Volatile Organic Compounds									
Naphthalene	—	—	—	—	—	—	—	—	—

Table 2 1
(Continued)

Chemical	Federal MCL ¹	Federal MCLG ²	State RCRA Groundwater Protection Standards ³	State MCL ⁴	State Basic Standards for Groundwater ⁵	State-Specific Standards for Groundwater ⁶			CDPHE PQL ⁷
						Table 1 Human Health	Table 3 Agriculture	Table 5 Chronic	
Metals									
Selenium	50	50	10	50	—	10	—	20	—
Vanadium	—	—	—	—	—	—	—	100	—

¹ National Primary Drinking Water Regulations 40 CFR 141

² Maximum Contaminant Level Goals 40 CFR 141.50

³ 6 CCR 1007.3 264.94

⁴ CRS 25 1 107 25 1 108 25 1 109 and 25 1 114

⁵ CDPHE/WQCC Basic Standards for Groundwater 3 11 0

⁶ CDPHE/WQCC Classification and Water Quality Standards for Ground Water 3 12 0

⁷ PQLs from CDPHE/WQCC Basic Standards for Groundwater 3 11 0

Listed as drinking water MCL in State groundwater standard Title A

Table 2-2
Comparison of Existing Concentrations and Groundwater PRGs
(State Basic Standards for Groundwater)
($\mu\text{g}/\ell$)

Chemical	Existing Concentration (grand mean) ¹	IHSS 119 1 Concentration (grand mean) ¹	Preliminary Remediation Goal ²
Volatile Organic Compounds			
Carbon Tetrachloride	81 20	360 6	1
Chloroform (total trihalomethanes)	4 68	16	6
1 1 Dichloroethane	2 10	4 94	1 010 ^b
1 2 Dichloroethane	6 10	3 7	1
1 1 Dichloroethene	283 23	1 270	7
1 2 Dichloroethene	N/A	N/A	328 ^b
cis 1 2 Dichloroethene	0 52	2 62	70
Tetrachloroethene	103 48	459 5	5
Toluene	4 68	16 48	1 000
Total Xylenes	3 23	6 09	10 000
1 1 1 Trichloroethane	363 29	1 630 1	200
1 1 2 Trichloroethane	2 69	7 67	3
Trichloroethene	371 65	1 667	5
Semi-Volatile Organic Compounds			
Naphthalene	N/A	N/A	N/A
Metals			
Selenium	283 4	503 2	10
Vanadium	8 68	43 3	256 ^b

¹ Final Phase III RFI/RI BRA J n 1994

² CDPHE/WQCC Bas Standards for Groundwater 3 11 0
 PQLs from CDPHE/WQCC Bas Standards for Groundwater 3 11 0

^b Programmatic Risk Based Preliminary Remediation Goals SGS 545 94 October 1994 (construction worker scenario)
 RCRA Groundwater Protection Standard 6 CCR 1007 3 264 94

2 4 1 Subsurface Soil General Response Actions

The GRAs identified for the OU 1 subsurface soil medium are no action institutional controls containment removal disposal in situ treatment and ex situ treatment These GRAs target the subsurface soil RAO identified earlier in Section 2 2 The RAO is focused on prevention of groundwater degradation from residual subsurface soil sources A brief description of each GRA is provided below

- **No Action** Required by CERCLA as a benchmark for comparison against other remedial action alternatives This implies that no direct action will be taken to alter the existing situation other than short and long term monitoring of site conditions
- **Institutional Controls** Refers to legal controls or management policies which minimize exposure to potential contaminants, such as restricting land use
- **Containment** For subsurface soils containment would consist of actions which minimize the spread of contamination and/or minimize the infiltration of groundwater which could be contaminated by subsurface soil contaminants
- **Removal** For OU 1 removal implies excavation of contaminated soils for treatment or disposal May be combined with extraction of contaminated groundwater in areas of subsurface soil excavation May also include dust control measures during excavation to minimize contaminant migration
- **Disposal** Disposal involves permanent deposition of excavated soils either in an on site or permitted off site disposal facility It includes disposal without treatment, if possible or disposal subsequent to treatment measures
- **In Situ Treatment** In general in situ treatment technologies seek to treat contaminants in place without extraction or removal of large volumes of soil Treatment would seek to remove destroy and/or immobilize contaminants through biological chemical or physical means This category includes bioremediation chemical oxidation/reduction soil washing thermal recovery enhancement and vapor extraction techniques
- **Ex Situ Treatment** This GRA is similar to in situ treatment except that contaminated soils would be removed before treatment above ground Treated soils would be disposed of on site or in a licensed disposal facility

2 4 2 Groundwater General Response Actions

The GRAs identified for the OU 1 groundwater medium are no action institutional controls containment removal in situ treatment and ex situ treatment These GRAs target the RAOs for groundwater The RAOs are focused on prevention of migration of contaminants in groundwater and on prevention of ingestion or inhalation of organic compounds in groundwater A brief description of each GRA is provided below

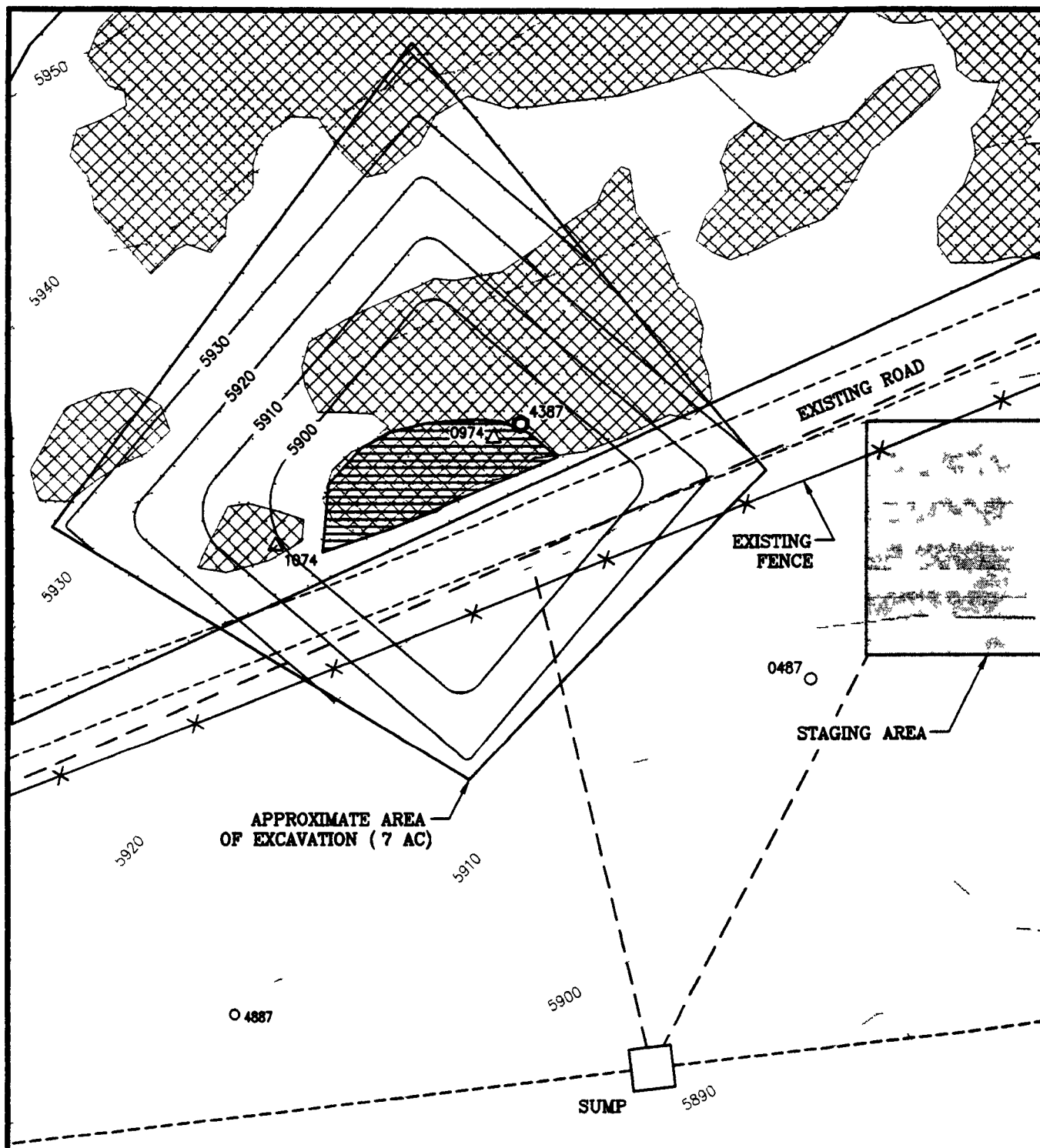
- *No Action* Required by CERCLA as a benchmark for comparison against other remedial action alternatives This implies that no direct action will be taken to alter the existing situation other than short and long term monitoring of site conditions
- *Institutional Controls* Refers to legal controls or management policies which minimize the public's exposure to potential contaminants Examples include controlling well placement and restricting land use
- *Containment* For groundwater containment would consist of actions which minimize the flux of vapor phase VOCs to the surface and/or minimize the migration of groundwater contaminants
- *Removal* For OU 1 removal implies extraction of contaminated groundwater for treatment in the existing Building 891 water treatment system or other facilities Extraction of contaminated groundwater in areas of DNAPL may be possible through soil extraction
- *In Situ Treatment* In general in situ treatment technologies seek to treat contaminants in place without extraction or removal of large volumes of groundwater or soil Treatment would seek to remove destroy and/or immobilize contaminants through biological chemical or physical means
- *Ex Situ Treatment* This GRA is similar to in situ treatment except that contaminants would be extracted/removed before treatment above ground Treated groundwater would be discharged through existing channels (i.e. the existing Building 891 water treatment system)

2 4 3 Volume and Area Estimates

A volume calculation was conducted for subsurface soils at IHSS 119 1 to estimate a volume for the potential residual DNAPL sources assumed to be present in IHSS 119 1. The amount of soil requiring remediation was estimated by visually inspecting the potential source areas described in the Phase III RFI/RI report and by assuming that subsurface soil remediation activities would attempt to remediate saturated zone soils to a depth of five feet into bedrock. Figure 2 1 depicts the potential soil excavation area identified for IHSS 119 1. The exact amount of contaminated subsurface soils cannot be calculated due to the limited data available for this medium. Limitations on data is typical of sites contaminated with residual DNAPLs. The excavation area however is estimated to contain approximately 17 500 cubic yards of soil.

Based on the results of the OU 1 Phase III RFI/RI report and the BRA in particular contaminated groundwater in OU 1 was found to contribute a significantly higher risk to those receptors exposed to IHSS 119 1 groundwater than to receptors exposed to groundwater from other locations in OU 1. IHSS 119 1 was designated a source location in the PHE for this reason. Other areas of the operable unit contain groundwater contaminant concentrations above detection limits however the concentrations are greatest at this IHSS (see Figure 2 2).

The quantity of groundwater requiring remedial action in the IHSS 119 1 source area cannot be calculated precisely because of seasonal variations in the water table. Instead a lower bound was estimated using computer codes that compared the bedrock topography beneath the IHSS to the water level data from wells located in this area. The wells used to identify and delineate this area were 0487 0974 1074 4387 32591 and 37991. This lower bound groundwater volume assumes groundwater beneath the IHSS is confined to the identified bedrock paleochannel. This assumption is valid only during low water table conditions. An upper bound cannot be calculated directly since during spring runoff the water table elevation rises above the bedrock paleochannel and no lateral extent of groundwater contamination specific to IHSS 119 1 can be measured distinctly from other groundwater at OU 1.



EXPLANATION

104

INDIVIDUAL HAZARDOUS SUBS AND SITE (IH) AND
IHSS DESIGNATION DASHED WHERE DISTURBED
DUPING INSTRUCTION OF FR NCH DRAIN



ACTUAL SCRAP METAL AND DRUM STORAGE AREAS
IN IH 119 BASED ON AERIAL PHOTOGRAPH



ACTUAL DRUM STORAGE AREA IN IH 119
BASED ON AERIAL PHOTOGRAPH

○ B301889

ALUMINUM WELL

△ 0271

P 385 WELL

○ BH1587

BOREHOLE

0 25 50



U S DEPARTMENT OF ENERGY

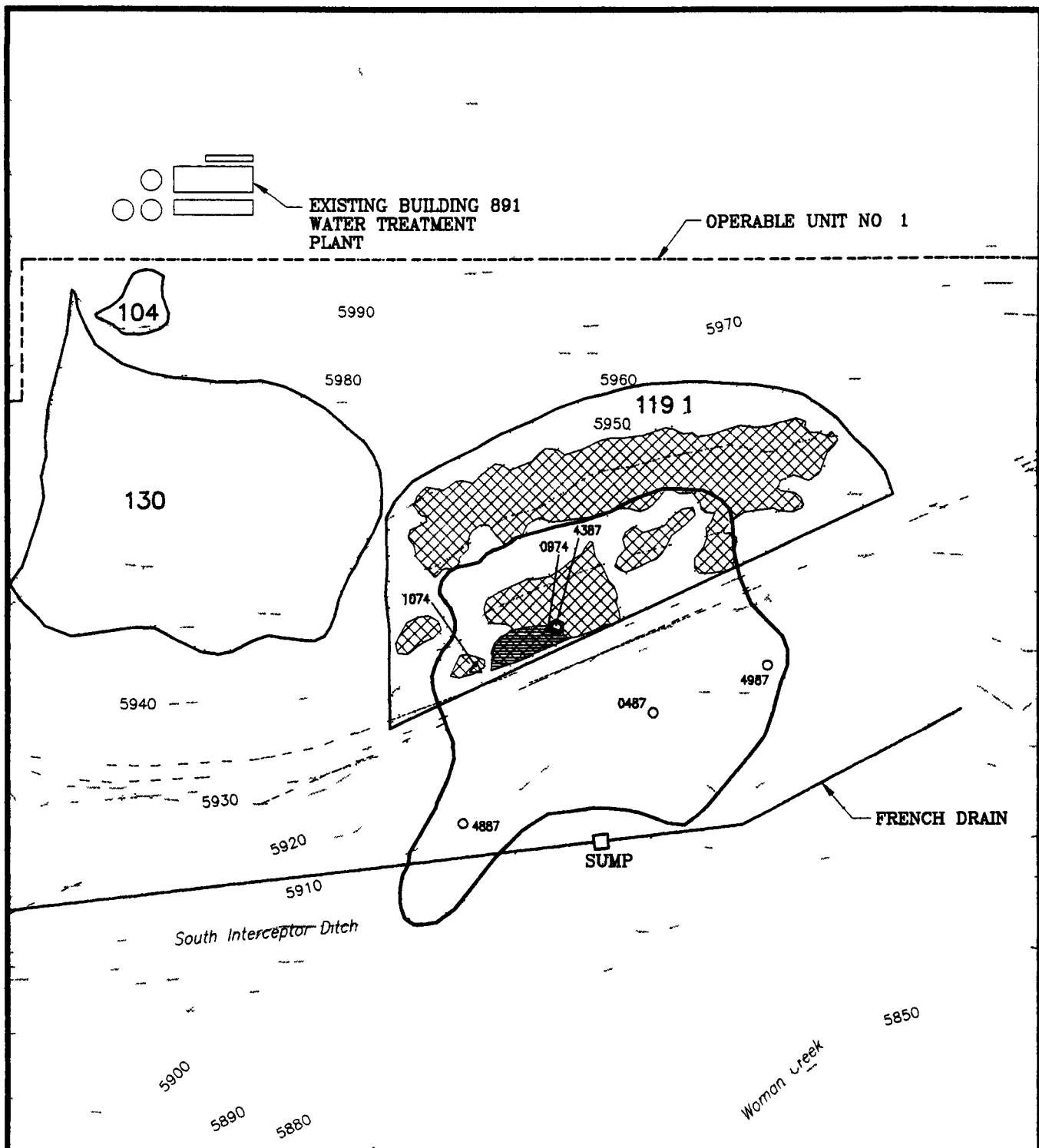
Rocky Flats Environmental Technology Site
Golden Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

**Potential
Soil Excavation Area
For IHSS 119 1**

Figure 2-1

UUT-EXC2.DWG



EXPLANATION

- INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) AND IHSS DESIGNATION DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN
- ACTUAL SCRAP METAL AND DRUM STORAGE AREA IN IHSS 119 BASED ON AERIAL PHOTOGRAPHS
- ACTUAL DRUM STORAGE AREA IN IHSS 119 1 BASED ON AERIAL PHOTOGRAPHS
- INFERRED EXTENT OF CONTAMINATION BASED ON 1/92 DETECTION
- 8301889 ALLUVIAL WELL
- 0271 PRE 1986 WELL
- BH1587 BOREHOLE



U S DEPARTMENT OF ENERGY Rocky Flats Environmental Technology Site Golden Colorado

IHSS 119 1
OPERABLE UNIT NO 1
CMS/Fs REPORT

Potential Extent of Contamination at IHSS 119 1

Figure 2-2

ADDED FROM JUN 994 QU
NAL PHAS RFI/ REPORT

TST-4124 DWG

The Phase III RFI/RI report contains several saturated thickness maps for OU 1 during a typical dry period. These maps were used to estimate the volume of contaminated groundwater in the source location when groundwater levels were at their lowest. Using an average porosity of 0.10 (DOE 1994a), the volume of groundwater estimated to be present in the southwest corner of IHSS 119.1 during the dry season is 80,000 gallons. This volume represents a single pore volume, although more than one pore volume would likely have to be removed to achieve RAOs. During wetter periods, groundwater in this area may rise above the paleochannel and thus result in much larger volumes requiring treatment.

In addition, the Phase III RFI/RI report estimated that the volume of available groundwater in OU 1 is between 5.0 and 5.8 acre feet (1.6 and 1.9 million gallons). The volume of groundwater estimated to be beneath IHSS 119.1 and the volume of groundwater beneath OU 1 are used to estimate remediation requirements; however, because groundwater elevations in OU 1 are highly dependent on seasonal variations in precipitation, these values are engineering estimates only.

2.5 Identification and Screening of Technologies and Process Options

This section summarizes the technologies and process options that were identified for remediation of OU 1. The section also describes the options that were maintained for further evaluation based on an initial screening of technologies. The initial screening considered technical implementability, applicability, and feasibility for site-specific contaminants and conditions. This initial screening eliminated remedial technologies and process options that did not warrant further consideration at OU 1. A summary of the initial screening of technologies for both groundwater and subsurface soils are presented in the following sections.

2.5.1 Identification and Screening of Technologies and Process Options for Subsurface Soils

The remedial technologies and process options initially identified for subsurface soils at OU 1 by GRA are listed in the following bulleted list:

Institutional Controls

- Access restrictions
 - Legal restrictions on land use

Containment

- Horizontal subsurface flow control
 - Subsurface drains
 - Grout curtains
 - Slurry walls
 - Sheet piling
 - Cryogenic barrier
- Vertical subsurface flow control
 - Grout injection
 - Block displacement

Removal

- Excavation
 - Loader/excavator/dozer
- Dust control
 - Dust suppressants
 - Temporary structures

Disposal

- On Site disposal
 - Engineered on site disposal facility
 - Permitted off site disposal facility

In situ Treatment

- Biological
 - Bioremediation
- Chemical
 - Chemical oxidation/reduction
- Physical
 - Soil flushing
 - Vitrification
 - Radio frequency/ohmic heating

- Vapor extraction
- Hot air/steam stripping with mechanical mixing

Ex Situ Treatment

- **Biological**
 - Bioremediation
 - Land application
- **Chemical**
 - Ultraviolet photolysis with chemical oxidation
 - Solvent extraction
- **Physical**
 - Soil washing
 - Stabilization/Solidification
- **Thermal**
 - Incineration
 - Thermal desorption
 - Vitrification

The preceding technologies and process options were systematically screened to reduce the number to a more representative group of remedial technologies and options. The screening was performed by examining the technical implementability of each technology and/or process option for subsurface soils at OU 1. Figure 2.3 depicts the subsurface soil remedial technology and process options screening activities.

Subsurface soil remedial technologies and process options that were maintained for further evaluation are as follows:

Institutional Controls

- Access restrictions
 - Legal restrictions on land use

Containment

- Horizontal subsurface flow control

- Subsurface drains
- Grout curtains
- Slurry walls
- Sheet piling
- Cryogenic barrier
- Vertical subsurface flow control
 - Grout injection
 - Block displacement

Removal

- Excavation
 - Loader/excavator/dozer
- Dust control
 - Dust suppressants

Disposal

- On Site disposal
 - Engineered on site disposal facility
 - Permitted off site disposal facility

In situ Treatment

- Biological
 - Bioremediation
- Physical
 - Soil flushing
 - Radio frequency/ohmic heating
 - Vapor extraction
 - Hot air/steam stripping with mechanical mixing

Ex Situ Treatment

- Biological
 - Bioremediation
- Chemical
 - Ultraviolet photolysis with chemical oxidation
 - Solvent extraction

- Physical
 - Soil washing
- Thermal
 - Incineration
 - Thermal desorption

2 5 2 Identification and Screening of Technologies and Process Options for Groundwater

The following remedial technologies and process options were identified for groundwater at OU 1

No Action

- Monitoring
 - Groundwater monitoring

Institutional Controls

- Access restrictions
 - Legal restrictions on well placement
 - Legal restrictions on land use

Containment

- Horizontal subsurface flow control
 - Subsurface drains
 - Grout curtains
 - Slurry walls
 - Sheet pilings
 - Cryogenic barrier
- Vertical subsurface flow control
 - Grout injection
 - Block displacement

Removal

- Passive removal
 - Subsurface drains

- Active removal
 - Horizontal and/or vertical extraction wells or sumps

In situ Treatment

- Biological
 - Bioremediation
- Chemical
 - Polymerization
 - Chemical oxidation
- Physical
 - Air sparging
 - Vapor extraction
 - Permeable treatment beds
 - In situ adsorption with wells (proprietary process)

Ex situ Treatment

- Biological
 - Bioremediation
- Chemical
 - Solvent extraction
 - Ultraviolet photolysis with chemical oxidation
- Physical
 - Gamma irradiation
 - Activated carbon or carbonaceous adsorbents
 - Air stripping
 - Membrane processes
 - Evaporation
 - Freeze crystallization
- Thermal
 - Incineration
 - Plasma arc discharge
 - Catalytic oxidation

These technologies and process options were systematically screened to reduce the number of options to a smaller and more representative number appropriate for the development of remedial alternatives. The screening was performed by examining the technical implementability of each

technology and/or process option for OU 1 groundwater The screening process is depicted in Figure 2-4 Technologies and/or process options that were maintained for further evaluation are as follows

No Action

- Monitoring
 - Groundwater monitoring

Institutional Controls

- Access restrictions
 - Legal restrictions on well placement
 - Legal restrictions on land use

Containment

- Horizontal subsurface flow control
 - Subsurface drains

Removal

- Passive removal
 - Subsurface drains
- Active removal
 - Horizontal and/or vertical extraction wells or sumps

In Situ Treatment

- Biological
 - Bioremediation
- Physical
 - Vapor extraction

Ex Situ Treatment

- Biological
 - Bioremediation
- Chemical
 - Ultraviolet photolysis with chemical oxidation

- Physical
 - Activated carbon or carbonaceous adsorbents
 - Air stripping
- Thermal
 - Plasma arc discharge
 - Catalytic oxidation

2.6 Evaluation and Selection of Representative Process Options

Remedial technologies and process options determined to be implementable at OU 1 were subjected to a more detailed evaluation to determine which process options should be used to develop alternatives. This more detailed evaluation was performed by comparing the ability of each process option to satisfy three criteria, effectiveness, implementability and cost.

Site specific conditions were considered in the evaluation of remedial technologies and process options. The following site characteristics were prominent factors in the evaluation:

- In general, levels of contamination in groundwater are relatively low.
- Contaminant distribution is largely sporadic or ubiquitous.
- Aqueous concentrations at IHSS 119.1 indicate the potential for DNAPLs.
- Underlying low permeability unweathered bedrock surface serves to channel groundwater flow.
- Overall low permeability and high degree of heterogeneity of saturated unconsolidated surficial materials contributes to preferential flow potential.

The evaluation of process options for subsurface soils is presented in Figure 2.5 while the evaluation of process options for groundwater is presented in Figure 2.6.

Rather than evaluating each potential process option, representative process options were designated to represent a class of remedial technologies that could be applied at OU 1. This improves the efficiency of the evaluation and allows for flexibility in the final selection of

process options within the chosen class of remedial technologies. Preference was given to technologies and process options which address both groundwater and subsurface soil contamination at OU 1.

Considering these factors, the following representative process options were selected for alternative development:

- Groundwater monitoring
- Legal restrictions on well placement
- Legal restrictions on land use
- Subsurface drains
- Horizontal and/or vertical extraction wells or sumps
- Loader/excavator/dozer
- Hot air/steam stripping with mechanical mixing
- Vapor extraction
- radio frequency (RF)/ohmic heating

The evaluation of process options to treat extracted groundwater favored the selection of the existing Building 891 water treatment system. Since the system has been proven to effectively treat the contaminants present in OU 1 groundwater (except CCl_4 , planned modifications to the system will effectively address this deficiency) and since the capital costs have already been incurred for designing and constructing this system, this process option is the most favorable for aboveground treatment of groundwater. Thus, other process options for ex situ treatment of groundwater, including plasma arc discharge, catalytic oxidation, and air stripping, were not considered in the development of remedial action alternatives. Plasma arc discharge and catalytic oxidation have prohibitive operating costs for low contaminant concentrations such as those at OU 1. Air stripping does not destroy or immobilize contaminants and would require treatment of large quantities of off gases.

The limited ability to uniformly and appreciably remove contaminated groundwater from the low permeability heterogeneous unconsolidated materials, combined with the complex nature of the bedrock system beneath OU 1, favored treatment that would remove residual sources (e.g., DNAPL zones) to the greatest extent possible. Removal of these sources should be conducted

in a manner that minimizes the potential for mobilizing contaminants to move further into the bedrock system as well as introducing new potential contaminants to the subsurface. Consequently, process options such as surfactant flushing are not appropriate. This is the case because the subsurface geology may seriously limit uniform distribution of surfactants in the subsurface, meaning treatment effectiveness throughout the entire contaminated zone may not be significantly increased. Further, the decreased surface tension induced by surfactants can enhance the mobility of contaminants through otherwise relatively impermeable materials. OU 1 bedrock has been characterized as fractured, meaning a decreased surface tension between DNAPLs and groundwater could cause significantly greater contaminant migration into bedrock. Finally, surfactants will adversely affect operation of the Building 891 water treatment facility, meaning an additional surfactant recycle unit operation would be necessary prior to water treatment. The increased capital costs of a recycle system along with the high operating costs for separation processes, such as surfactant recycle, negate the marginal effectiveness increase in treatment associated with surfactant flooding.

Other process options that require injection of additional fluids into the subsurface (e.g., bioremediation and soil flushing) are also not favorable at OU 1. The complex nature of OU 1 subsurface geology and the limited availability of groundwater make systems which rely on homogenous distribution of flushing agents or nutrients difficult to implement. Preferential groundwater flow pathways and tightly consolidated soil matrices make injection difficult to control. Moreover, since DNAPL zones are likely to exist in isolated areas, injection technologies are unlikely to be effective in remediating these areas.

In addition to the problems related to preferential flow through the heterogeneous low permeability materials, bioremediation was not included in the development of remedial action alternatives for the following additional reasons:

- The effectiveness of bioremediation at OU 1 is limited by the nature of the contaminants identified. Although laboratory studies have shown up to 90 percent reduction of TCA and TCE concentrations under ideal conditions, researchers are skeptical as to the full scale applicability of bioremediation under field conditions, stating that implementation of biodegradation of chlorinated hydrocarbons in field

situations may be limited by the toxicity of high concentrations of these compounds to microorganisms and by the slow rate of degradation possible (Baker et al 1994)

- PCE a major OU 1 contaminant is a highly refractory compound (resistant to decay) for which there is no established field method for degradation at rates which make treatment practical
- Bioremediation is not effective in treating inorganics such as selenium An aboveground treatment system could be used to remove selenium from extracted groundwater however this would most likely limit the effectiveness of reinjection systems that recycle nutrients or non indigenous bacteria
- Site conditions at OU 1 particularly fluid circulation limit the technical implementability of bioremediation at OU 1 The Phase III RFI/RI demonstrates the lack of a consistent defined water source beneath IHSS 119 1 Well and borehole data in the area have indicated varying water table levels and depths of saturated zones Implementation of bioremediation at OU 1 would require injection of large volumes of water to provide nutrients and/or non indigenous bacteria to treatment zones This might mobilize and spread contamination and accelerate slumping at OU 1 Experience with installation of the french drain system has indicated that slumping is a serious concern for unsaturated conditions and would be more serious for the highly saturated conditions that would be required to implement bioremediation

For the medium of subsurface soils thermal desorption was chosen as the representative process option for ex situ treatment of contaminated subsurface soils Thermal desorption offers the most cost effective method of contaminant removal for the sporadic contaminant distribution found at OU 1 Chemical and physical treatments such as ultraviolet photolysis chemical oxidation solvent extraction and soil washing require the addition of liquids to effect a mass transfer from solid to liquid media The resulting liquid could not be treated in the Building 891 water treatment facility without pre treatment due to the presence of strong oxidizers solvents and/or dissolution agents Thus a separate liquid treatment process to treat the secondary liquid waste would be required The capital costs associated with such a treatment process as well as the expense of solvents washing agents and oxidation reagents exceed the energy costs associated with thermal processes Thermal desorption was selected over incineration due to the low levels of contamination at OU 1 and the relatively low heating value of chlorinated organics The higher temperatures required for incineration would require excessive secondary fuel sources Since thermal desorption operates at significantly lower temperatures energy costs

would be substantially lowered relative to incineration

Due to the limitations of soil flushing and bioremediation discussed previously standard and thermally enhanced vapor extraction process options were selected as in situ subsurface soil treatments for alternative development and will be used in conjunction with limited groundwater pumping to remove contaminated groundwater and potential residual DNAPLs from OU 1 subsurface soils

Other options retained for alternative development include excavation which was retained to provide conceptual variety to the alternatives presented for remediation at OU 1 Excavation could be used to remove subsurface soils or to locate pools of contaminated groundwater ensuring that any residual DNAPL zones are removed In addition, process options were retained that would result in the assembly of limited or minimal action alternatives including groundwater monitoring use of the existing French Drain system, and institutional controls These options are also discussed in Section 3 0

2 7 Existing IM/IRA Treatment System

The existing Building 891 water treatment system (UV/H₂O₂ and ion exchange) will be essential for proposed remedial action alternatives for OU 1 and other operable units that require aboveground groundwater treatment The system constitutes a comprehensive process treatment train for treating water contaminated with organic and inorganic (including radionuclide) contaminants (see Figure 2 7) The system consists of a collection and pumping system to supply the treatment facility an influent storage and transfer system separate treatment systems for organic and inorganics contaminants and an effluent storage and discharge system The system is designed for a 30 gpm flow rate capacity and has equalization tanks to normalize treatment rates

The french drain collection and pumping system includes the recovery well pump located in IHSS 119 1 and two french drain sump pumps These pumps are normally controlled by level

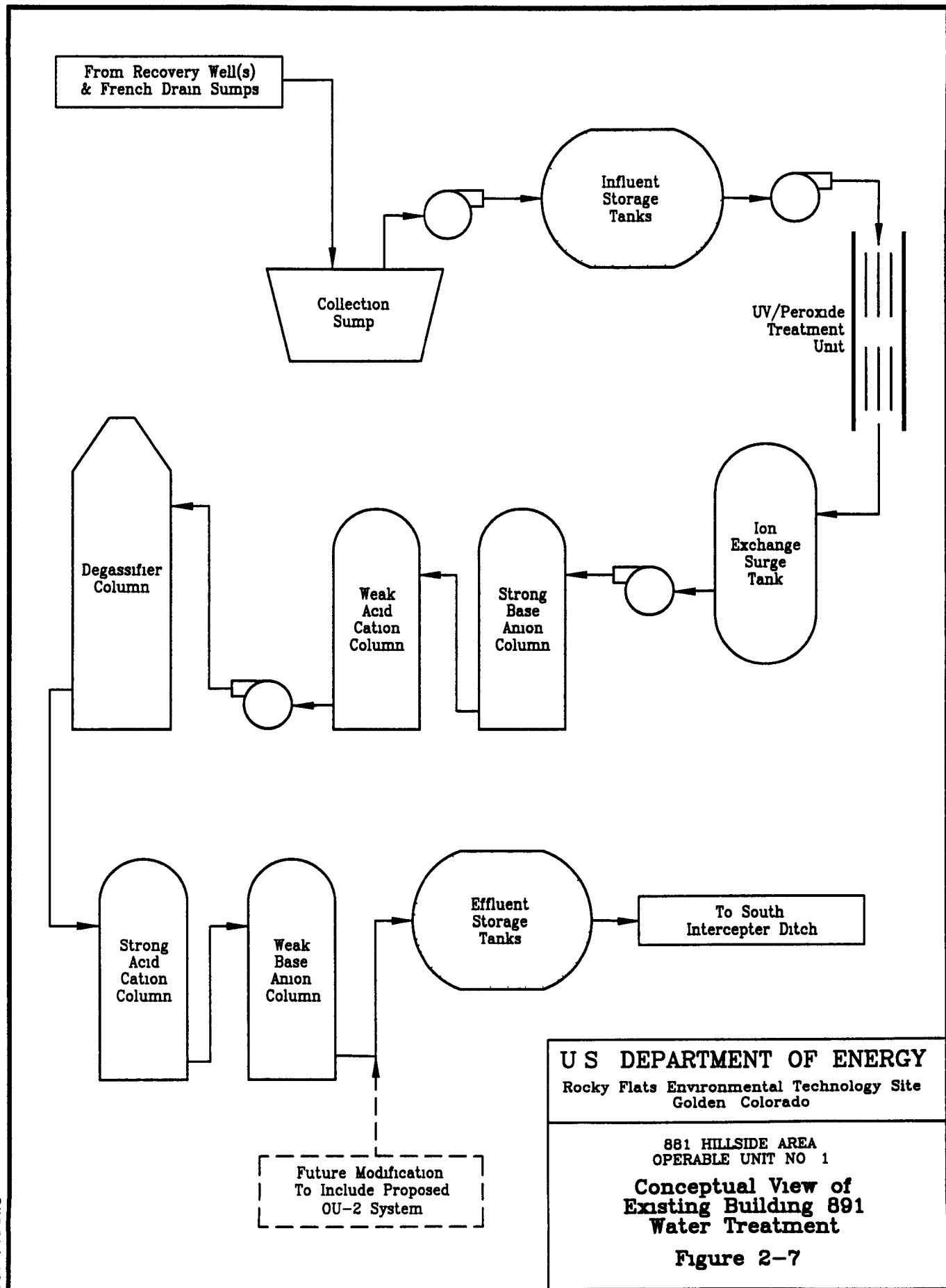
switches in the well or sump that determine whether the pumps operate. The collection system connects to the influent transfer system which includes two influent equalization tanks and two influent transfer pumps. The influent transfer pumps supply water from the influent equalization tanks to a UV/H₂O₂ treatment unit at a constant rate. The UV/H₂O₂ unit is designed to destroy organic contaminants in the influent stream.

Treatment efficiency depends on flow rate (residence time), H₂O₂ concentration, and UV wavelength intensity. The system has a design throughput of 30 gpm or 14,400 gallons per day (gpd) with an 8 hour operating shift. It uses 50 mg/l of H₂O₂ with sixteen 15 kW UV lamps providing an equivalent power of 240 kW for breaking down organics.

When the water leaves the UV/H₂O₂ system, it enters the ion exchange system which consists of the ion exchange surge tank, four columns containing beds of ion exchange resins, and a degassing tower. The ion exchange system processes the water in the following sequence:

1. The water enters the ion exchange surge tank and is pumped at a constant rate into the first ion exchange column. This column contains 28 cubic feet of Ionac A-440, a strong base anion resin, for removing uranium.
2. The water then flows directly to the second column which contains 32 cubic feet of Ionac CC, a weak acid cation resin, for removing heavy metals.
3. The water then enters the degassing tower to allow carbon dioxide and other gases produced during the UV/H₂O₂ process to escape. Excessive gas content in the ion exchange columns could cause short circuiting of the resins, thereby reducing the efficiency of the system.
4. The water is then pumped to the third ion exchange column which contains 56 cubic feet of Ionac C 240H, a strong acid resin, for removing hardness and metals.
5. The water then enters the fourth and final column which contains 56 cubic feet of Ionac AFP 329, a weak base anion resin, for removing anions.
6. The water, which is now treated, is stored in one of three effluent storage tanks and discharged by gravity feed.

OU1-PTS DWG



3 0 DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES

This section presents the alternatives that were assembled for remediating the groundwater medium at OU 1. These alternatives were assembled using the technologies identified in Section 2.0 which summarizes the evaluation and selection of technologies and process options.

Utilizing the existing Building 891 water treatment system is an integral component of all the alternatives presented in this section with the exception of the No Action alternative. The Building 891 treatment system is currently used for treating water from OU 1 and may also be used for treating contaminated water from other areas of the RFETS. Planned modifications to the system will allow it to treat higher concentrations of contaminants prior to initiation of any remedial activities at OU 1. The details of the planned modifications are discussed in Section 2.0.

3.1 Introduction

Remedial action alternatives were developed by combining process options selected as representative based on results of the evaluation of process options and technologies. Process options were combined to develop alternatives ranging from treatment alternatives that eliminate or minimize the need for long term management to limited or no action alternatives. This range of alternatives includes containment options that involve little or no treatment but achieve RAOs by preventing exposures or by reducing the mobility of contaminants. The No Action alternative was developed to provide a baseline alternative against which other alternatives could be compared. In all cases, the alternatives were developed with the goal of achieving the RAOs of preventing inhalation, ingestion, and dermal contact with VOCs, preventing migration of contaminants from subsurface soils to groundwater, and protecting Woman Creek surface water from contamination as presented in Section 2.0 by combining appropriate GRAs to form site specific remediation strategies.

The alternatives that were developed for remediation of OU 1 are the following:

- Alternative 0 No Action
- Alternative 1 Institutional Controls with the French Drain
- Alternative 2 Groundwater Pumping and Soil Vapor Extraction
- Alternative 3 Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement
- Alternative 4 Hot Air Injection with Mechanical Mixing
- Alternative 5 Soil Excavation with Groundwater Pumping

Figure 3 1 depicts a summary of the development of remedial action alternatives. The figure presents the GRAs and process options that were combined to form the various alternatives. After developing alternatives for remediation of OU 1, the alternatives were evaluated in detail, and the results of this analysis are presented in the Detailed Analysis of Alternatives in Section 4 0.

3 2 Remedial Action Alternatives

Groundwater remedial action alternatives were developed that could potentially achieve the RAOs described in Section 2 0. The primary risk pathways that determined which GRAs would be used to develop alternatives were based on the OU 1 BRA, which indicated that ingestion of groundwater and inhalation of vapors rising up through unsaturated soils were of most concern. The following alternatives were designed to achieve RAOs by removing and destroying the contaminants in groundwater, removing subsurface sources of residual contamination, restricting access to wells positioned within the boundaries of OU 1, and/or limiting access to the entire site. These alternatives assume that surface soil hotspots would be removed prior to commencing remedial activities and would be put into temporary storage for treatment with similar wastes from OU 2 or shipped off site for immediate treatment and/or disposal.

3 2 1 Alternative 0. No Action

The No Action alternative was developed to meet the requirements of the NCP which specifies that a No Action alternative should be developed regardless of site specific conditions (EPA 1990a) The No Action alternative provides a baseline against which other alternatives can be compared during the detailed analysis of alternatives The No Action alternative uses the results of the BRA to define exposure levels to receptors at the site under existing conditions and does not include any remedial activities

The existing French Drain collection system would be discontinued under this alternative Collection of groundwater from the existing collection well and French Drain would be discontinued Groundwater would be allowed to flow down the hillside and around the French Drain toward Woman Creek

The only activity associated with the No Action alternative is groundwater monitoring to detect changes in contaminant concentrations or migration patterns Monitoring would begin immediately and would continue until it is determined that monitoring is no longer required Existing wells no longer deemed necessary would be abandoned as appropriate

There is no remedial time frame for this alternative since the alternative relies solely on natural degradation and attenuation processes to meet RAOs For the purposes of detailed analysis a 30 year monitoring time frame is assumed in accordance with EPA guidance

3 2 2 Alternative 1. Institutional Controls with the French Drain

Alternative 1 seeks to achieve RAOs by restricting access to wells impacted by OU 1 contaminants through institutional controls while continuing to treat groundwater collected by the existing French Drain at the Building 891 water treatment system Institutional controls would also be employed to prevent unauthorized construction and groundwater usage in all areas of OU 1 Degradation of groundwater would be minimized by continued containment and

treatment of groundwater Subsurface residual sources would eventually be depleted by dissolution to groundwater The capture of groundwater with the French Drain and use of institutional controls to reduce exposure are both established remedial options This alternative targets groundwater in the areas of IHSS 119 1 south of Building 881 and a portion of IHSS 119 2 for remediation Institutional controls would be employed throughout OU 1

The existing French Drain and Building 891 treatment system would continue to operate until it is deemed no longer necessary The modifications discussed in Section 2 0 are assumed to have been completed for the purposes of detailed analysis Groundwater monitoring would begin immediately and continue for as long as required to verify that contaminant concentrations in groundwater have been permanently reduced below appropriate limits Wells no longer deemed necessary for monitoring would be abandoned as appropriate

The Building 891 treatment system has a design flow rate of 30 gpm but the system currently operates intermittently as volumes of collected groundwater dictate Current average flow from OU 1 sources is estimated at 10% of the design capacity or 3 gpm (DOE 1994d) The rate of treatment is dependent on the amount of groundwater available at the French Drain

Wastes generated as a result of this alternative will be managed in compliance with applicable regulations The wastes include spent GAC from the off gas treatment system and Building 891 water treatment system regenerant solution from ion exchange resin regeneration from the Building 891 water treatment system and wastes associated with monitoring well installation such as drill cuttings and decontamination water The decontamination water could be sent to Building 891 The regenerant solution from the spent ion-exchange resins will be pH neutralized and sent to Building 374 for evaporation in accordance with current operational practices The spent GAC will be sent off site for regeneration Alternative 1 however does not present any administrative or legal difficulties since it represents a continuance of current operations at OU 1

There is no remediation time frame defined for Alternative 1 since the French Drain system is

currently operational and would continue to operate until acceptable contaminant concentrations are achieved. Based on current operations of the existing French Drain system, it is reasonable to assume that due to the slow groundwater collection rate, operation of the French Drain system would be required for an extensive period of time. Experience with similar remedial actions at DNAPL contaminated sites suggests extremely long time frames for complete residual depletion. For the purposes of detailed analysis cost estimates, a 30-year time frame for remedial activities is assumed based on EPA guidance.

3.2.3 Alternative 2. Groundwater Pumping and Soil Vapor Extraction

This alternative seeks to achieve RAOs by dewatering the IHSS 119.1 source area using conventional pumping techniques and the implementation of a localized SVE system. Risk from contaminated groundwater will be eliminated by extraction and treatment, while further degradation of groundwater will be minimized by removal of residual DNAPL sources through SVE. The combined technologies proposed under this alternative are considered emerging technologies, which may be more effective combined than when applied individually. In general, this alternative targets only the identified source area within IHSS 119.1, although additional vapor extraction wells could be installed in other areas to treat suspected DNAPL sources based on the results of a detailed soil gas survey to be conducted prior to remediation.

SVE would assist the vaporization and subsequent recovery of contaminants present in the saturated soils, unsaturated soils, and groundwater at OU 1. The technology targets contaminants that have partitioned to the aqueous phase in the subsurface, adsorbed onto subsurface soils, exist as pools of DNAPL, or occupy soil pore spaces as vapor. Groundwater residing in shallow pools throughout IHSS 119.1 would be extracted via the existing French Drain and one to three additional recovery wells. Collected groundwater would be treated by the existing Building 891 water treatment system or another appropriate facility with the modifications discussed in Section 2. These same areas, once desaturated, would be subjected to SVE to enhance the removal of any residual contaminants.

In general soil vapor extraction is an in situ physical treatment technology that has been used primarily to remediate soil and groundwater contaminated with VOCs. A typical SVE system consists of either a single or if necessary a network of vapor extraction wells screened at depths consistent with the contaminated soils. If multiple vapor extraction wells are used they are usually joined together by a common header pipe. Makeup or clean air replacing the contaminated soil gas removed through SVE enters the soil either passively via the ground surface and/or inlet wells or actively via air injection wells. Channeling or short circuiting, of the makeup air may be minimized and the air redirected through the desired treatment zones, by the placement of a geotextile liner on the ground surface surrounding the SVE wells.

The basic principle behind SVE involves inducing vapor flow through the unsaturated zone towards an extraction well by applying a vacuum to that well. Contaminants volatilized from the soil matrix and those that are already in the vapor phase are swept by the carrier gas flow (air) to the extraction well(s). The carrier gas also tends to increase the volatilization of any aqueous phase or free phase DNAPL contaminants in the vicinity. There are three main factors that control the performance of an SVE operation: (a) the vapor flow rate through the unsaturated zone, (b) the flow path of carrier vapors relative to the location of the contaminants and (c) the chemical composition of the contaminants (Johnson et al. 1989).

To successfully design and operate an SVE system site geology and contaminant properties must be considered. Site geology can have a significant influence on a vapor extraction well's radius of influence. Geological factors include depth to groundwater, subsurface soil/rock type and subsurface permeability which must be great enough to allow carrier vapors to strip VOCs from the subsurface matrix and carry them to an extraction well. Soil vapor extraction performance is also dependent on the characteristics of the contaminants targeted for extraction. A compound is a likely candidate for SVE if it has a vapor pressure of 1.0 mm or more of mercury at 20°C and a dimensionless Henry's Law constant greater than 0.01 (Danko 1989). Table 3.1 presents these values for the primary VOCs under consideration at OU 1 as well as other general physical and chemical data. These five VOCs were chosen for evaluation of SVE due to their high concentrations relative to other VOCs detected and their wide range of Henry's Law constants.

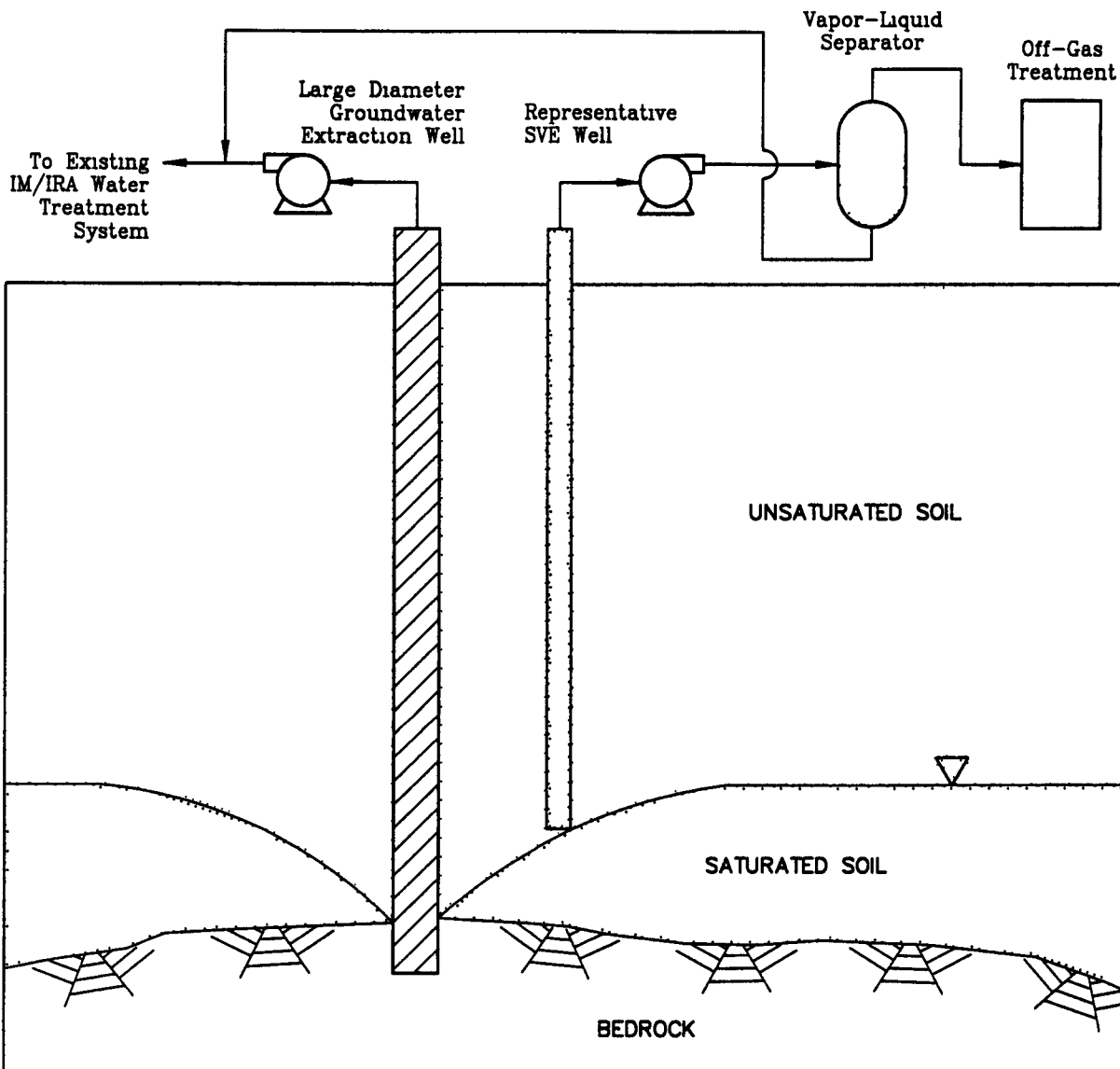
Table 3 1
Physical and Chemical Properties of the Primary VOCs in Groundwater

Chemical	Formula	Molecular Weight ^a	Specific Gravity ^b	Boiling Point (C) ^b	Aqueous Solubility (mg/l)	Vapor Pressure (mm Hg)	Henry s Law Constant (Dimensionless) ^a
Carbon Tetrachloride	CCl ₄	153 82	1 59	76 5	757	90	1 002
1 1 Dichloroethene	C ₂ H ₂ Cl ₂	96 94	1 22	37 0	2 250	182	1 414
Tetrachloroethene	C ₂ Cl ₄	165 83	1 62	121	150	17 8	1 076
1 1 1 Trichloroethane	C ₂ H ₃ Cl ₃	133 39	1 34	75 1	1 500	100	0 599
Trichloroethene	C ₂ HCl ₃	131 38	1 45	87	1 100	57 9	0 378

^a from *Basics of Pump-and Treat Ground Water Remediation Technology* EPA/600/8 90/003 Office of Research and Development March 1990

^b from *Selecting Process Equipment vol 1* Woods McMaster University Canada 1990

^c at 20 C



Not To Scale

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Conceptual View of
SVE System

Figure 3-2

The use of these five compounds for analysis of the SVE alternatives should yield a good approximation of the actual performance of SVE for the site. The data shown in Table 3.1 indicate that all of the VOCs under consideration are amenable to recovery by SVE. A conceptual view of the proposed configuration of an SVE system is presented in Figure 3.2.

For this alternative it is assumed that approximately 36 vapor extraction wells would be installed in IHSS 119.1 and in other areas if deemed appropriate. A detailed soil gas survey would be conducted prior to installing these wells in order to determine exact well locations and any additional areas warranting remediation. Wells would be installed to a depth of approximately 20 feet and would be 4 to 6 inches in diameter. These wells would be operated cyclically to enhance recovery and would be used in combination with a granular activated carbon (GAC) unit to treat extracted vapors. Cyclical operation would allow contaminant concentrations in soil gas to return to near equilibrium levels during non operation, thus increasing the mass of contamination removed per volume of air extracted. Higher concentrations in the extracted air stream would decrease operating costs, while the cycled operation of various wells would allow the use of less expensive equipment due to decreased capacity needs.

The existing French Drain and Building 891 treatment system would continue operation during remedial activities to collect any contaminated groundwater existing downgradient of the treatment area and not removed through dewatering activities. After source removal and groundwater plume remediation, the French Drain could be decommissioned. Without regular pumping of the sump pumps located in the French Drain, water would begin to flow around the French Drain and continue toward Woman Creek. Groundwater monitoring would be employed for the entire duration of this alternative to ensure water flowing around the drain meets PRGs.

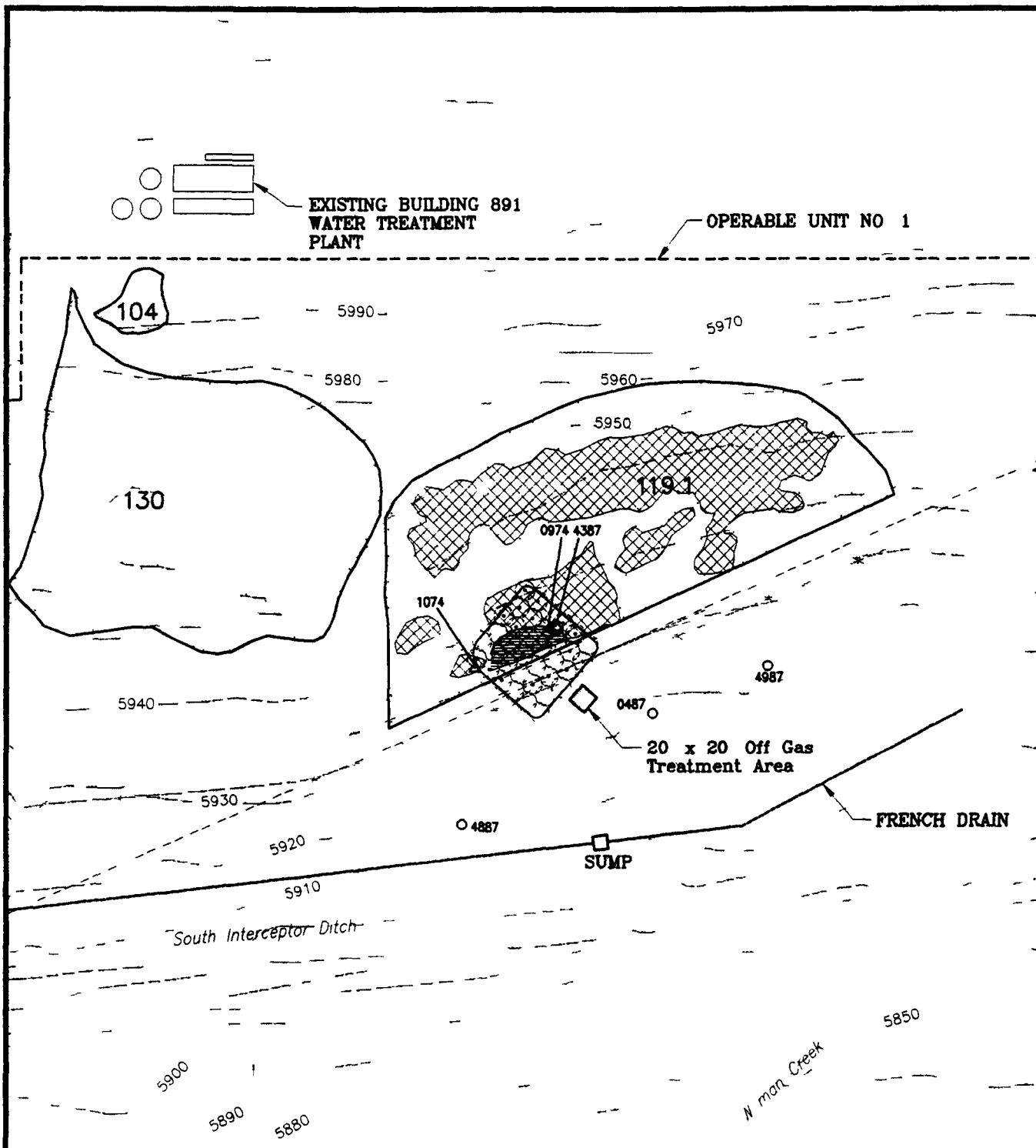
Wastes generated as a result of this alternative will be managed in compliance with applicable regulations. The wastes include spent GAC from the off gas treatment system and Building 891 water treatment system, regenerant solution from ion exchange resin regeneration from the Building 891 water treatment system, and wastes associated with well installation such as drill cuttings and decontamination water. The decontamination water could be sent to Building 891.

The regenerant solution from the spent ion exchange resins will be pH neutralized and sent to Building 374 for evaporation in accordance with current operational practices. The spent GAC will be sent off site for regeneration.

The total remediation time frame associated with this alternative is approximately seventeen years. Estimated time frames associated with various component remedial activities are three months for the detailed soil gas survey, three months for mobilization/demobilization, and four years for treatment. Once the SVE system was decommissioned, the French Drain would continue operating for 10 years to remediate the groundwater plume currently flowing down the hillside. Monitoring would continue for an additional three years after decommissioning the French Drain to ensure that contaminant levels remain below PRGs. The GAC air treatment unit for SVE unit would most likely require a National Emission Standards for Hazardous Air Pollutants (NESHAPs) permit to operate; however, this would not present any unusual administrative constraints.

3.2.4 Alternative 3. Groundwater Pumping and Soil Vapor Extraction With Thermal Enhancement

This alternative seeks to achieve RAOs through combining SVE as described in Alternative 2 with thermal recovery enhancement techniques. Groundwater extraction is employed to treat contaminated groundwater, while SVE with thermal enhancement is used to remove residual contamination sources. The alternative considers two innovative treatment technologies that can effect an increase in subsurface soil temperatures — radio frequency heating and electrical resistance (ohmic) heating. Both technologies are discussed below, although for the purposes of detailed analysis, radio frequency heating is analyzed further, whereas ohmic heating is merely assumed to be potentially applicable at OU 1 and is not included in the detailed analysis of alternatives. A plan view of the alternative, including the treatment area with approximate well locations, is included as Figure 3.3.



EXPLANATION

- INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHS) AND IHS DESIGNATION DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN
- ACTUAL SCRAP METAL AND DRUM STORAGE AREAS IN IHS 119 BASED ON AERIAL PHOTOGRAPH
- ACTUAL DRUM STORAGE AREA IN IHS 119 BASED ON AERIAL PHOTOGRAPHS
- SVE WELL WITH 10' RADIUS OF INFLUENCE

- 8301889 ALLUVIAL WELL
- 0271 PPE 1986 WELL
- 8H1587 BOREHOLE



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Plan View for
Alternative #3

Figure 3-3

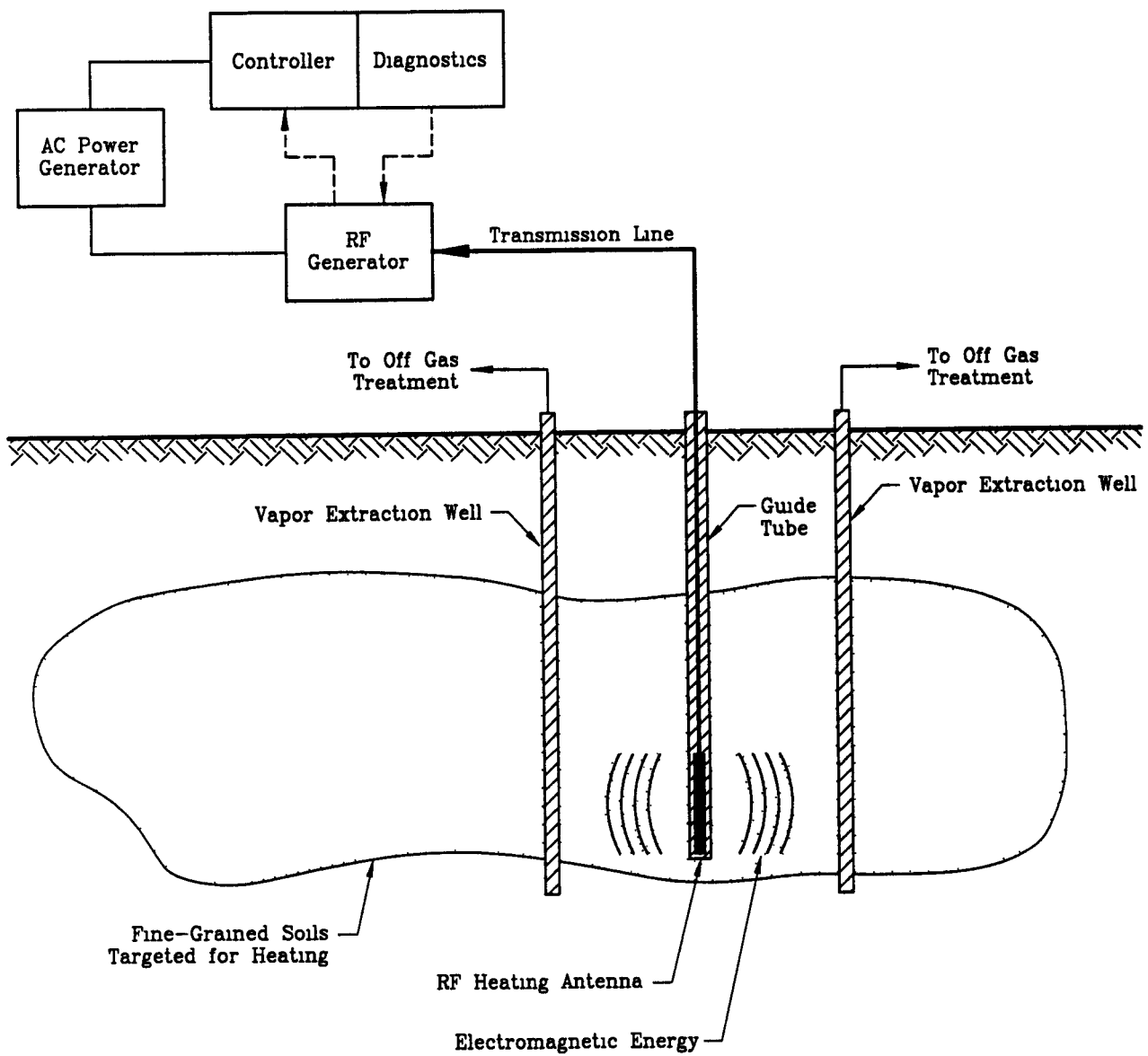
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Radio Frequency Heating

RF heating was selected as one of the two representative process options to effect an elevation in temperature of the subsurface materials at OU 1 that are contaminated with those contaminants that are VOCs. RF heating is an innovative in situ technology for volatilizing organic constituents in soil and water as well as vaporizing pore space moisture. The technology is desirable since additional chemicals are not introduced into the subsurface and no special arrangement (e.g. grids) are necessary as in conventional ohmic heating.

The in situ RF heating process requires minimal intrusion, using 3 to 6 inch diameter boreholes containing strategically placed antennae in the desired treatment area. Through a combined mechanism of ohmic and dielectric heating, the temperature in the media is raised and the volatile and semivolatile organic constituents are volatilized (Kasevich 1992). Volatilized organics are then collected with the vapor extraction system and subjected to further treatment. RF heating is expected to supplement vapor extraction in a manner that allows for quicker recovery of VOCs from certain areas of the subsurface. Specifically, heating VOC source areas can expedite VOC recovery in the vapor form (i.e. hotspots are likely to contain aqueous DNAPL and adsorbed phase VOCs which would be driven to vapor under elevated temperature conditions). Figure 3-4 illustrates a simple application of RF heating combined with vapor extraction for this alternative.

The dielectric loss of a material (i.e. the amount of energy a material dissipates as heat when placed in a varying electric field) contributes to the heating of the contaminated media. An indicator of a material's ability to successfully absorb electromagnetic energy is its dielectric constant. Most soils have suitable dielectric constants that allow for effective treatment. Water and/or soil moisture is vaporized by RF energy; however, steam is transparent to RF energy and does not continue to absorb radiation energy. While the steam may become superheated, this occurs only by energy conduction from the solid media and not from direct electromagnetic energy absorption. The steam in turn serves to heat surrounding materials, enhancing additional vaporization. Thus, water and/or soil moisture does not present a hindrance to the treatment.



Note Figure represents information provided in part by KAI Technologies Inc

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**Conceptual View of
 Radio Frequency
 Heating System**
Figure 3-4

process. Fractures and voids within the contaminated matrix also do not present treatment problems since thermal conduction is not the primary heat transfer mechanism. Densely packed soils are well suited to this treatment as are other consolidated geologic materials. A variety of heating profiles can be generated by manipulating the subsurface placement of RF antennae, their operating frequencies, and the phase output of the different antennae. Virtually uniform heating within a specified volume can be achieved with minimal heating of surrounding material using a properly designed configuration. Thus, localized treatment can be attained with proper design.

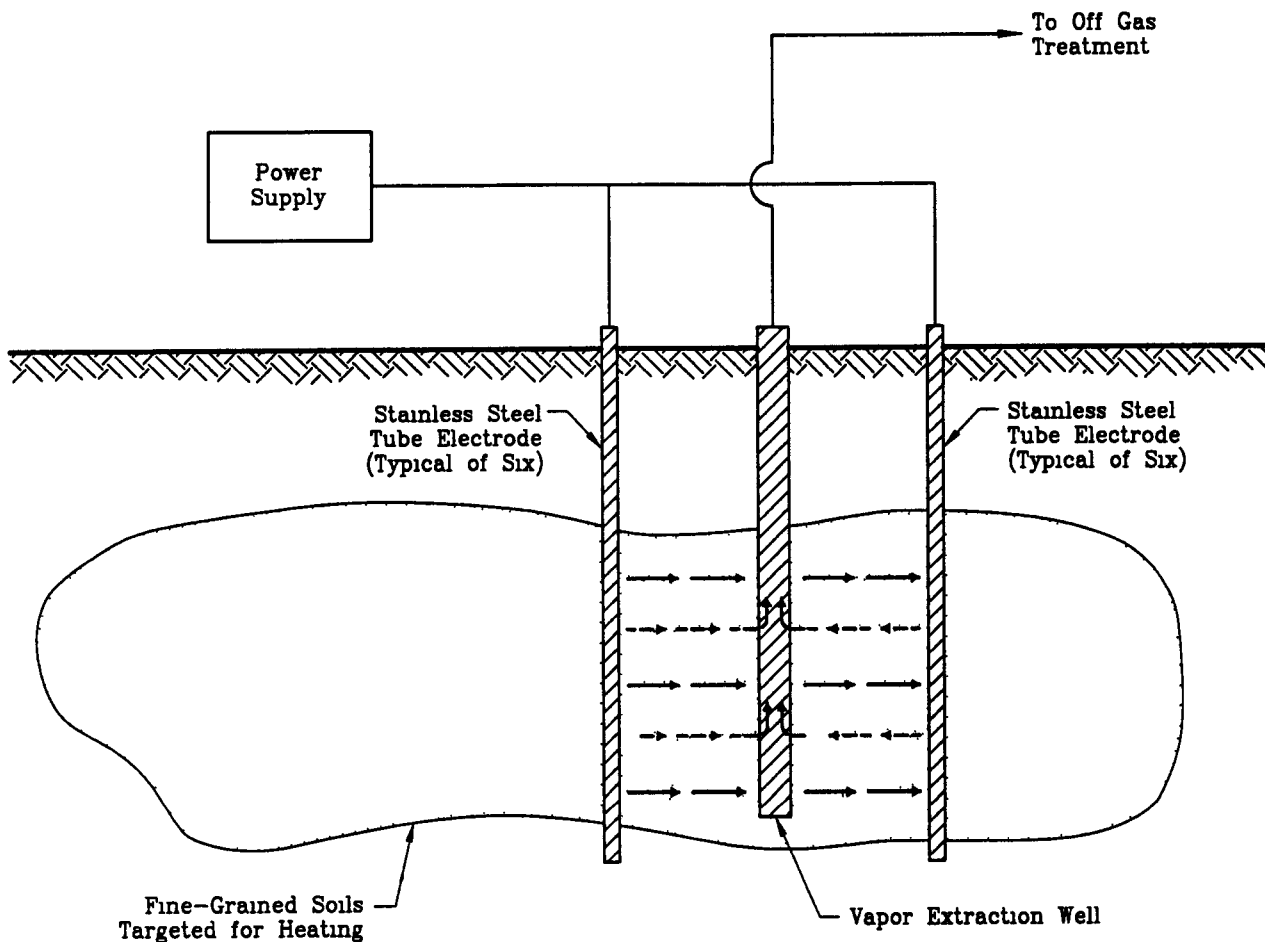
RF heating has been shown to be capable of increasing soil temperature to approximately 500°F. This temperature would be great enough to volatilize both sorbed and potentially dissolved phase contaminants (e.g., aqueous phase) in the subsurface materials as well as drive off any moisture in nearby pore spaces. The temperature of the subsurface medium would be raised gradually; therefore, vapor extraction wells would be able to extract vapor as it is generated. The heating and resulting steam/vapor generation rate could be controlled so that the capacity of the vapor recovery system would not be exceeded. Such control would prevent the spread of contamination by steam plume expansion. Also, RF heating would only be implemented in the vicinity of a vapor extraction well. Placement of an RF heating antennae in this manner would provide assurance that RF heating would not lead to a spread of contamination. A vapor recovery system supplemented with RF heating would likely require additional air drying capacity since it is expected that the RF heating system would lead to the extraction of a greater amount of soil moisture than conventional vapor extraction.

The primary piece of equipment of this alternative is the applicator antenna, which is placed in a borehole. This antenna is generally a flexible component of varying length that radiates electromagnetic energy in the form of radio frequency waves. The energy originates from a generator at the surface and is transmitted to the antenna via a metal coaxial cable. Standard drilling equipment can be used to complete a borehole. The borehole is generally cased with fiberglass or a similar material that is transparent to electromagnetic radiation. The antenna can be placed in vertical or horizontal boreholes. Also, several antennae may be used concurrently in various areas with elevated contaminant concentrations.

Locations of RF antennae and vapor extraction wells for cleanup of the volatile subsurface contaminants at OU 1 are contingent on detailed design through which the optimum system design would be defined however it is assumed under this alternative that RF heating antennae would be installed in vapor extraction wells near the vapor extraction wells being operated The number of vapor extraction wells required would range from 20 to 40 depending on saturation levels The spacing between boreholes can range depending on the RF heating frequency depth interval of heated volume and properties of the materials heated An array of multiple boreholes can provide uniform heating of a given subsurface volume Control devices monitor performance of the RF generator and adjust the outputs to optimize system performance Soil gas monitoring wells must be in place in the vicinity of the RF heating antennae These wells are necessary to monitor for potential increased migration of contaminant outside of the radius of influence of the vapor extraction well(s)

Ohmic Heating

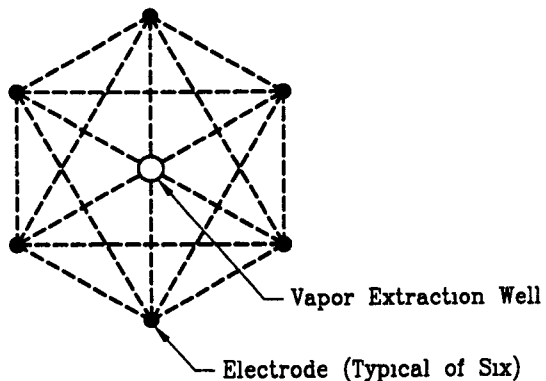
Ohmic heating was also selected as one of the two representative process options to effect an elevation in temperature of the subsurface materials at OU 1 that are contaminated with volatile contaminants This technology is considered an emerging technology which is currently being examined under the OU 2 treatability study program Like RF heating ohmic resistance heating is an innovative in situ technology for enhancing the performance of soil vapor extraction by volatilizing organic constituents in soils and groundwater and by vaporizing pore space moisture Unlike RF heating however ohmic resistance heating results from the transmission of an electrical current through the media targeted for cleanup As such a prerequisite for ohmic heating is that the media must be able to conduct an electrical current Ohmic heating requires the placement of a grid of electrodes and sometimes the addition of water in the area targeted for remediation The process requires only minimal intrusion and has most often been implemented using six electrodes installed in a hexagonal pattern to the depth of the contaminants with a vapor extraction well placed in the center of the pattern as shown in Figure 3 5 (Aines et al)



EXPLANATION

- Flow of Electrical Current Between Electrodes
- - -→ Vapor Flow Toward Vapor Extraction Well

Plan View of Grid Arrangement



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Conceptual View of
Electrical Resistance
Heating System

Figure 3-5

Six or three phase power can be used to supply current to the installed electrodes. There is some benefit with six phase power in that a more uniform heating pattern can be realized in the area being treated (Buettner et al). However the increased uniformity comes at the expense of needing additional equipment to split normal three phase power into six phase. Electrodes are usually constructed of stainless steel tubing which can also serve as passive air inlets.

The principle of ohmic heating is simple. Basically electrical currents are made to flow between electrodes placed in a contaminated region causing resistance heating (much the same way that passing an electrical current through an oven heating element generates resistance heating). Current flow through subsurface materials tends to be greatest in fine grained soils such as silts and clays. These types of soils are generally less permeable than sands and gravel thus heating the clays and silts can drive off contaminants contained therein that are not easily accessible with conventional soil vapor extraction. Once the volatile contaminants are driven out of the less permeable clays and silts into the more permeable sands and gravel they are more susceptible to recovery by vapor extraction. As with RF heating soil moisture can be heated with ohmic heating to generate steam. Steam can provide additional stripping of adsorbed contaminants. Also the removal of soil moisture can increase the air flow permeability of the soil being treated thus enhancing the capability of vapor extraction to remove contaminants (but lessening the ability to continue heating the subsurface with electrical current).

The primary pieces of equipment needed to support ohmic heating include stainless steel piping (for electrodes), a 60 Hz power supply, an optional six phase transformer, thermocouples for monitoring subsurface temperature, and a vapor recovery/treatment system. Electrode grids may be placed at various locations targeted for treatment. Extracted vapors from multiple locations may be directed to a central treatment location or to individual treatment units.

The location of the electrode grid(s) and vapor extraction well(s) for cleanup of the volatile subsurface contaminants at OU 1 are contingent on treatability test results in which the optimum system design would be defined. However for this alternative it was assumed that one grid would be installed at IHSS 119.1. This grid would have six electrodes inserted to approximately

20 feet below the surface in a hexagonal arrangement making up a circle with a diameter of approximately 20 feet. Additional grids would be required to remediate the entire site. As previously discussed the conceptual approach presented for RF heating is carried forward for detailed analysis. The information presented here on ohmic heating may be beneficial if it is selected as the preferred technology prior to implementation of any remedial actions at OU 1.

A soil gas survey consisting of approximately 100 probes will be conducted to determine exact locations of wells and to identify any additional areas warranting remediation. There is a possibility that DNAPL pools will be encountered during the remediation and may present a fire hazard or health and safety concern. Procedures will be in place during the remediation to minimize any hazards or concerns.

Based on historical photographs of the drum storage area at IHSS 119 1 and an assumed lateral DNAPL dispersion through the subsurface soil the dimensions of the primary contaminant source were estimated at 100 feet by 100 feet by 20 feet. Because SVE extraction rates are optimal in dry soil, the treatment zone will be dewatered by groundwater extraction wells. Initial dewatering is required with intermittent operations to keep the treatment zone dewatered throughout the entire remedial action.

Extracted groundwater will be pumped to the French Drain where it will be transferred to the Building 891 water treatment system described in Section 2. The French Drain will continue to capture groundwater for 10 years following source removal activities in order to capture the contaminated groundwater plume. Three additional years of monitoring will be used to verify that the groundwater concentrations remain below PRGs.

The SVE system will operate as described in Alternative 2 with the exception that radio frequency antennae will be placed in wells as necessary to maintain elevated subsurface temperatures. Approximately 36 vapor extraction wells fitted for radio frequency antennae will be drilled with a 30% radius of influence (ROI) overlap in the treatment area. Based on the OU 2 SVE treatability study it is estimated that 4 inch diameter wells will produce a well head

pressure of 120 inches of water and a ROI of 10 feet under normal operating conditions. With an estimated soil permeability of 0.05 darcy, it is anticipated that vapor extraction rates will approach 10 standard cubic feet per minute (scfm). The treatability study at OU 2 indicated that extraction rates are optimal during dry conditions so the treatment area will be dewatered during the remediation. Extraction rates documented during the SVE treatability study at OU 2 decreased from 40 scfm to 5 scfm during wet conditions.

Intermittent operation will be utilized to increase the removal efficiency of the SVE system. Preferential vapor channeling, or short circuiting, will be minimized by a geotextile liner. Increased vaporization caused by the elevated temperatures will reduce remediation time as well as increasing removal efficiencies of the contaminants.

Extracted vapors will be transferred to an off gas treatment system such as GAC unit. A GAC system would require two skid mounted GAC vessels placed in series and each containing 1,500 pounds of activated carbon each. The GAC will need to be replaced approximately every three months, i.e., 1,500 pounds every 6 weeks, depending on the COC concentrations, loading efficiencies, competitive adsorption rates, and type of carbon. The spent GAC will be regenerated at an off site facility.

Vapor sampling from portals near the wells and GAC units will be used to determine the effectiveness of the enhanced SVE system, replacement rates for the GAC vessels, temperature and humidity. In addition, pressure will be monitored at the wells and probes to determine extraction rates, radius of influence, and if short circuiting is occurring.

Wastes generated as a result of this alternative will be managed in compliance with applicable regulations. The wastes include spent GAC from the off gas treatment system and Building 891 water treatment system, regenerant solution from ion exchange resin regeneration from the Building 891 water treatment system, and wastes associated with well installation such as drill cuttings and decontamination water. The decontamination water can be sent to Building 891. The regenerant solution from the spent ion exchange resins will be pH neutralized and sent to

Building 374 for evaporation in accordance with current operational practices The spent GAC will be sent off site for regeneration

This alternative would require a remediation time frame of approximately 15.5 years This includes three months for a detailed soil gas survey three months for mobilization and demobilization two years for treatment ten additional years of French Drain operation and three years of groundwater monitoring to ensure that groundwater concentrations remain below PRGs This would be required to verify that all residual sources of DNAPLs in the subsurface have been remediated NESHAPs permits would be required for any other gas treatment systems

3.2.5 Alternative 4. Hot Air Injection with Mechanical Mixing

This alternative seeks to achieve RAOs through an innovative in situ technology that combines hot air stripping with vigorous mixing of subsurface media Contaminated groundwater is remediated through extraction and treatment in the Building 891 facility, while the subsurface residuals are addressed by source removal with hot air injection and mechanical mixing

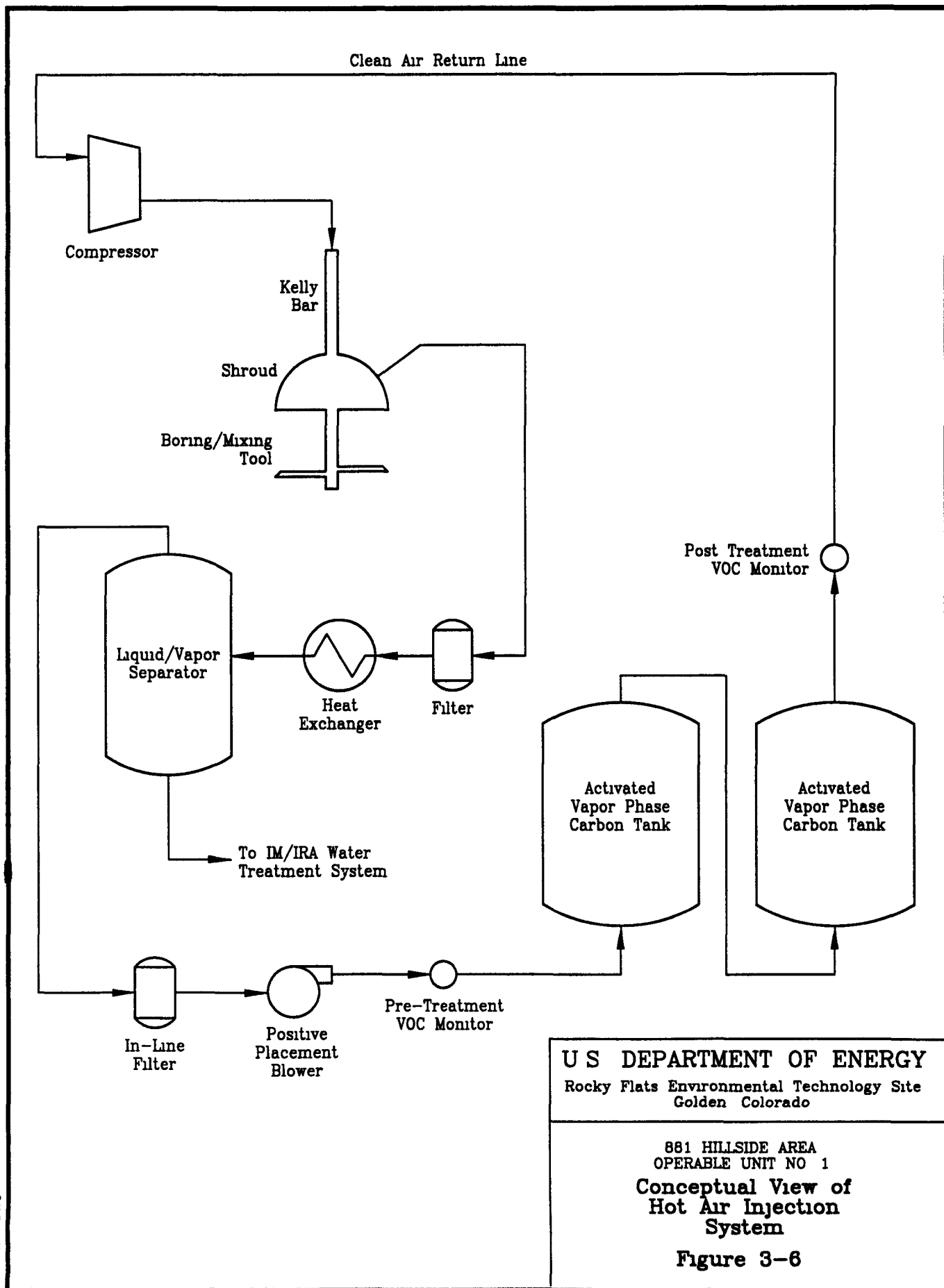
This alternative targets the identified source area in IHSS 119.1 but additional areas could be included based on the results of a detailed soil gas survey preceding treatment The IHSS 119.1 source area is estimated at 100 feet by 100 feet with a depth to bedrock of approximately 20 feet

This innovative technology operates under the same basic principles of SVE and thermal enhancement discussed in the previous alternatives but combines these with vigorous mechanical mixing to increase treatment effectiveness by ensuring carrier gas contact with all contamination The mixing of the soils by an auger allows homogenous treatment avoiding the possibilities of preferential subsurface flow channels that could result in non uniform treatment This system represents an innovative combination of technologies to increase treatment effectiveness and decrease treatment time

The primary treatment system in this alternative consists of a caterpillar mounted drill rig with specialized drilling equipment. The drill equipment is capable of delivering treatment reagents such as hot air or steam via piping in a hollow drill bit shaft. The drill bit has a cutting/mixing blade which can vary in diameter from 4 to 12 feet. Groundwater extraction wells would be placed in previously treated soil columns. Dewatering of a small area prior to treating the initial soil column would be accomplished via an extraction well drilled with conventional drilling equipment. Extracted groundwater would be treated through the existing Building 891 treatment system. The drill rig can produce up to 350 000 ft lbs of torque sufficient to provide excellent mixing of subsurface soils as the drill bit descends through the soil column. The drill bit also has multiple injection ports for hot air delivery. The multiple ports provide uniform delivery of hot air throughout the treatment zone. The caterpillar mounted drill rig is moved from one treatment zone to another sequentially until the entire site is remediated. The treatment columns or drill shafts are overlapped by 30% to ensure adequate treatment throughout the entire site. 4 to 6 columns can be treated per day depending on site conditions. A conceptual view of the hot air injection and mechanical mixing technology is included as Figure 3 6.

For volatile compounds such as those at OU 1 a negative pressure shroud is placed over the entire treatment zone to capture off gases for delivery to an onboard off gas treatment system. Mats are placed under and around the rig to ensure that contaminants do not reach the atmosphere by surfacing outside the shroud. The shroud vacuum is connected to an off gas treatment system. A vapor liquid separator removes entrained liquids for delivery to the Building 891 water treatment system. Vapors continue through the off gas treatment system. For the contaminants and concentrations at OU 1 vapor phase carbon adsorption is the preferred treatment option. Once treated the air is recycled to a compressor and heater and reinjected to the subsurface.

Wastes generated as a result of this alternative will be managed in compliance with applicable regulations. The wastes include spent GAC from the off gas treatment system and Building 891 water treatment system regenerant solution from ion-exchange resin regeneration from the Building 891 water treatment system and wastes associated with monitoring well installation.



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Conceptual View of
Hot Air Injection
System

Figure 3-6

OU1-WTS DWG

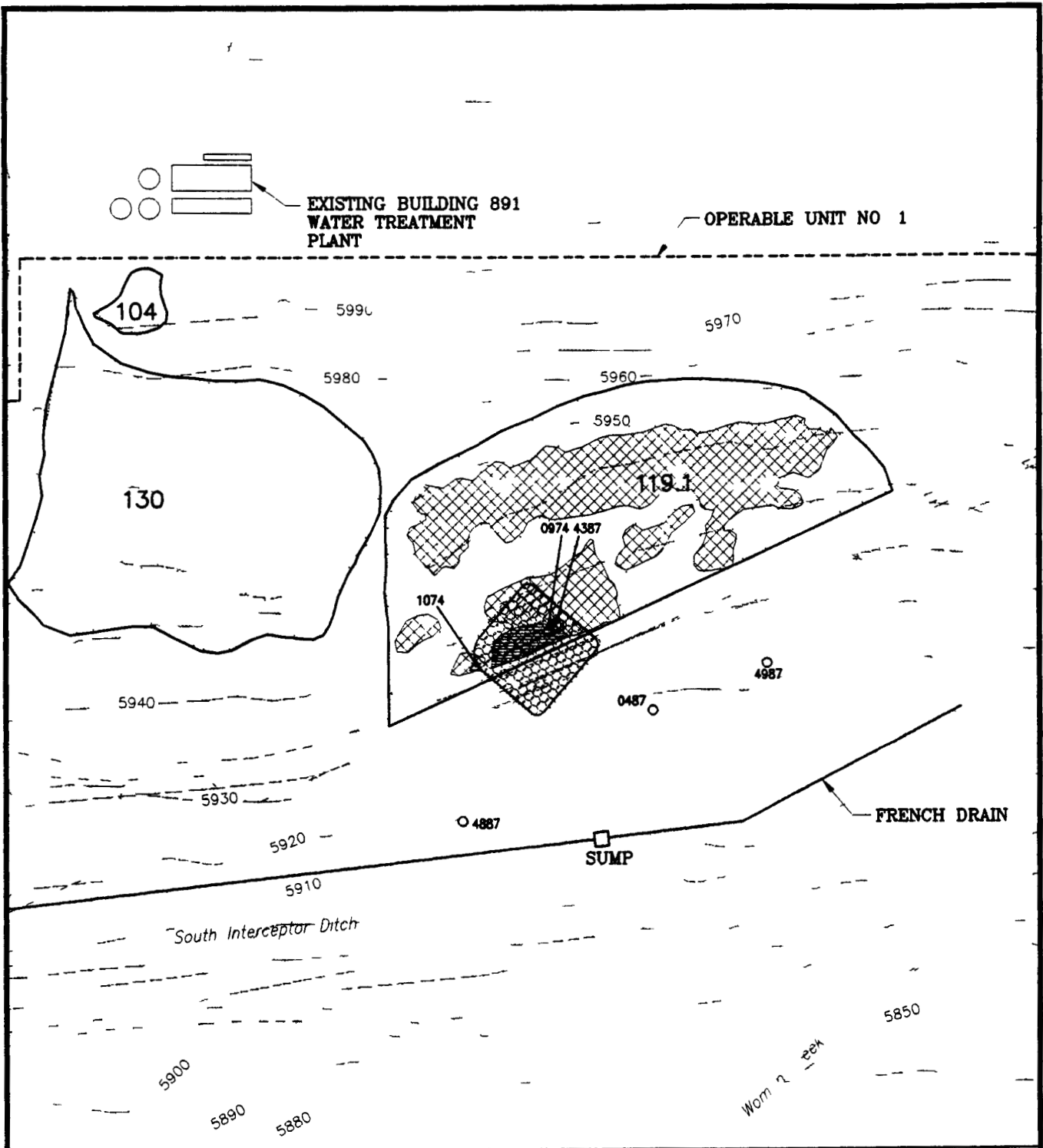
such as drill cuttings and decontamination water. The decontamination water can be sent to Building 891. The regenerant solution from the spent ion exchange resins will be pH neutralized and sent to Building 374 for evaporation in accordance with current operational practices. The spent GAC will be sent off site for regeneration.

Approximately 141 soil columns will be necessary to remediate the identified source area in IHSS 119.1 which could be accomplished in three months. The total remedial time frame for this alternative is 13.75 years, with three months for the detailed soil gas survey, three months for mobilization and demobilization, three months for treatment, ten additional years of French Drain operation to remediate the contaminated groundwater plume, and three additional years of monitoring to ensure groundwater concentrations remain below PRGs. A plan view for this alternative is included as Figure 3.7.

3.2.6 Alternative 5: Soil Excavation with Groundwater Pumping

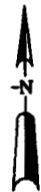
This alternative is intended to achieve RAOs through excavation of contaminated groundwater and soil beneath a discrete portion of the IHSS. This alternative differs from the in situ treatment alternatives in that a portion of unsaturated and potentially saturated soils at the IHSS would be excavated down to the water table to allow for the removal of localized groundwater contamination. The excavated soils would be treated by thermal desorption to minimize any further degradation of groundwater beneath the IHSS from residual DNAPLs present in the soils. This is a worst case scenario which would enable contaminated water to be located and subsequently removed. Such efforts may be required based on the current understanding of the hydrogeologic conditions at OU 1 which suggest complex geology in the area. Excavation and groundwater pumping are established remedial technologies which can be combined with no significant difficulties.

This alternative would require excavation of approximately 17,500 cubic yards of unsaturated and potentially saturated soils in the southwest corner of IHSS 119.1 based on the results of the Phase III RFI/RI (see Figure 2.1). Excavation of the required volume would result in an



EXPLANATION

- 104 INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) DESIGNATION DASHED WHERE DISURBED DURING CONSTRUCTION OF FRENCH DRAIN
 ACTUAL CRAP METAL AND DRUM STORAGE AREA IN IHSS 119 BASED ON AERIAL PHOTOGRAPHS
 ACTUAL DRUM STORAGE AREA IN IHSS BASED ON AERIAL PHOTOGRAPHS
 10 DIAMETER BORE HOLE
 ○ B301889 ALLUVIAL WELL
 △ 0271 PR 1986 WELL
 ○ BH1587 BOREHOLE



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Plan View for
Alternative #4

Figure 3-7

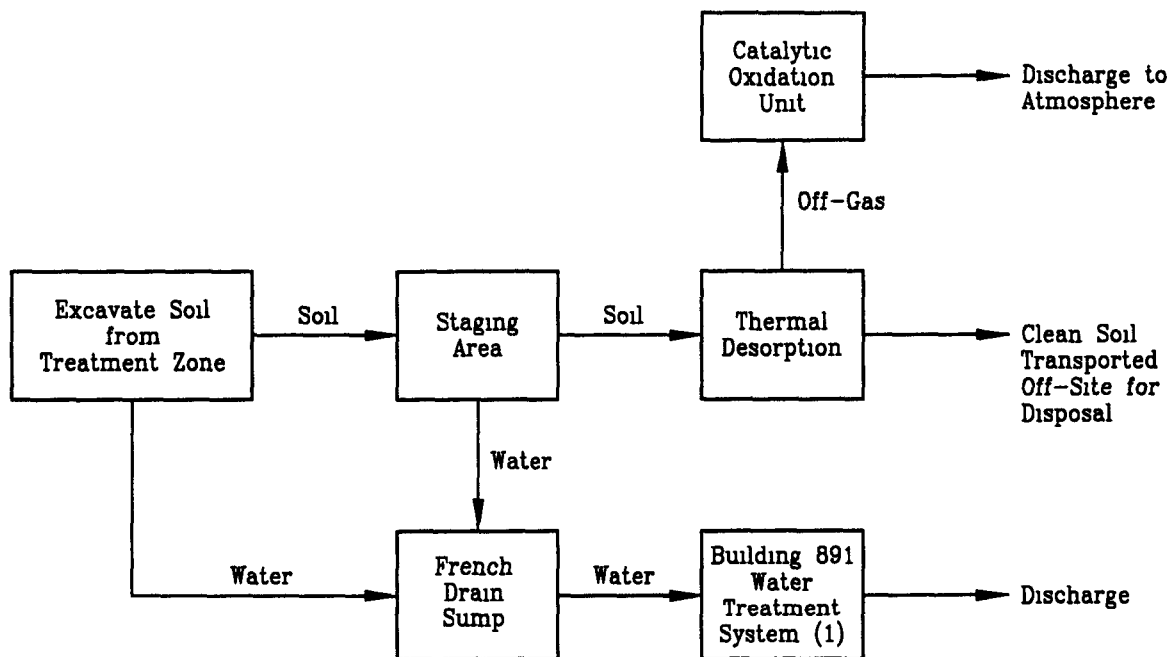
OU1 BRS/DWC

excavated area of 0.7 acres based on excavating a 100 ft by 100 ft area down to bedrock (20 ft) with sloping around the area of 2 to 1

Excavation would be terminated slightly below the underlying bedrock to ensure that all contaminated groundwater pools are reached. The groundwater would be collected using sump pumps installed within the excavation. Standard submersible pumps would be used to direct collected groundwater to the existing French Drain sump pumps. The groundwater would then be transferred to the Building 891 water treatment system at OU 1 for final treatment and discharge. A conceptual view of the excavation and treatment process is shown in Figure 3.8. A piping system from the excavation to the OU 1 treatment facility would be required and would most likely be constructed of PVC and buried to a sufficient depth to prevent freezing.

Surface soils located within the excavation area will be scraped and stockpiled on site to be treated with surface soil from OU 2 at a later time. The subsurface soil will be excavated and transported to a staging area for treatment. It is anticipated that the staging area can be constructed within 300 feet of the excavation. Management of the surface and subsurface soil will comply with 40 CFR 264 and may include creating a roof or other cover over the staging area to minimize precipitation onto the soil and prevent fugitive dust losses, landscaping the area to create adequate drainage, placing a pad or liner under the storage areas to prevent infiltration and limiting access to the storage sites. The actual excavation would be accomplished using conventional construction equipment although breathing apparatus may be included as part of the machinery or may be handled separately on an individual basis.

The excavated soil in the staging area will be dewatered and treated by a skid mounted thermal desorption unit to below detection limits for PCE, TCE, 1,1-DCE, CCl_4 , and 1,1,1-TCA. The treated soil should meet the RCRA Land Disposal Restrictions including restrictions for radionuclides and metal compounds prior to disposal in a permitted treatment, storage, and disposal (TSD) facility. It is assumed that an appropriate facility is located within 100 miles of the site. The treated soils could be disposed of on site; however, due to the administrative difficulties of delisting hazardous wastes, it has been assumed the treated soils will be shipped.



(1) See Figure 2-2

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Conceptual View of
Excavation and Treatment
Process

Figure 3-8

off site for disposal

Groundwater extracted from the excavation will be pumped to the French Drain where it will be transferred to the Building 891 water treatment system. The French Drain will continue operating for 10 years after remediation to collect contaminated groundwater. Groundwater monitoring will continue for an additional 3 years following French Drain discontinuation of French Drain operation to verify that the concentrations remain below the PRGs at the French Drain.

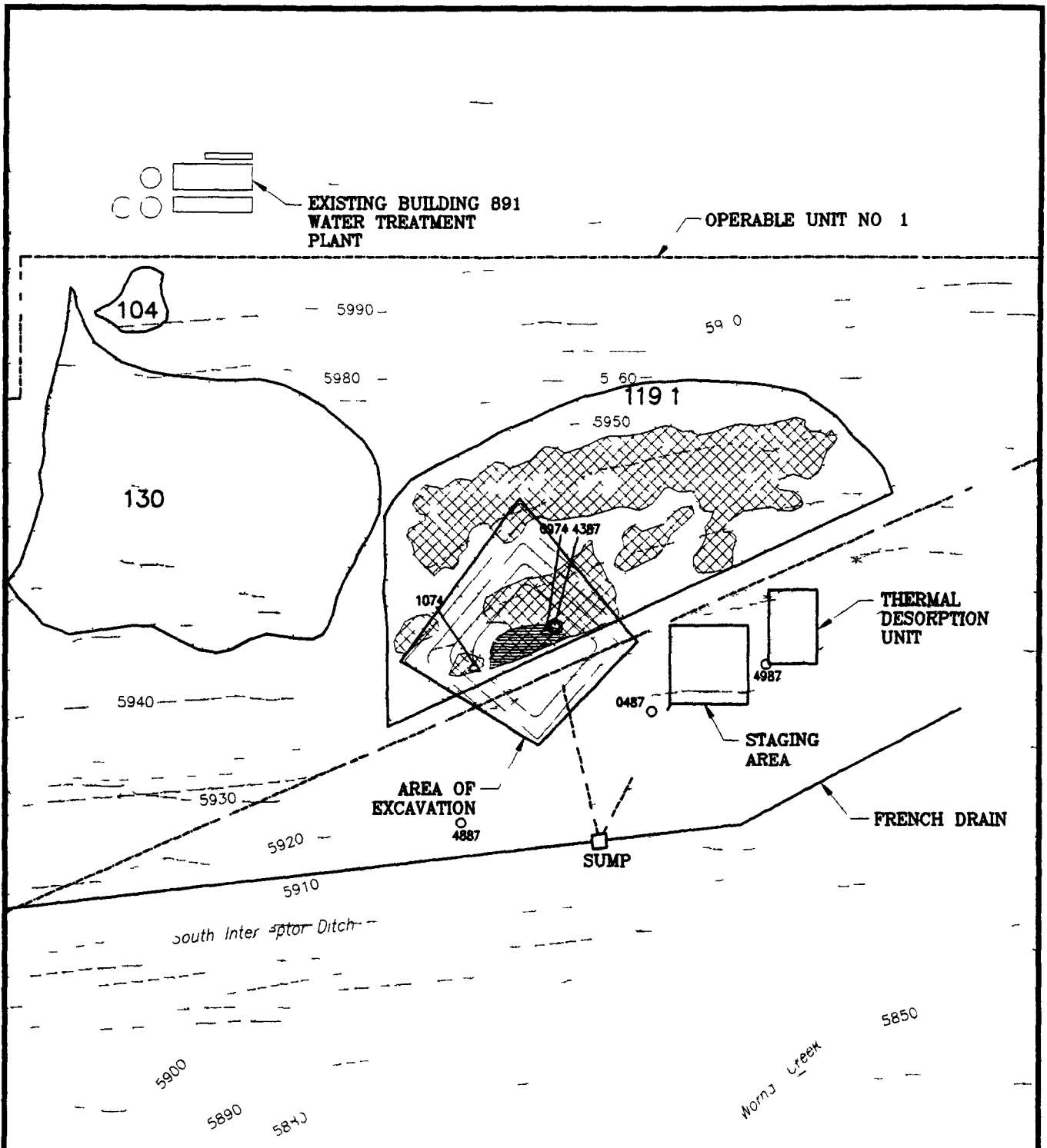
Radiological monitoring would be conducted for the duration of the excavation due to the potential presence of plutonium in the soils. Although Alternative 5 involves removal of the source of contamination to groundwater at IHSS 119.1, groundwater monitoring of groundwater would still be required once the remedial action is complete to verify that all sources of residual DNAPL contamination have been remediated. Short term monitoring of vapor concentrations in air would also be required during the excavation and prior to its closure.

A buried gas transmission line is located in the vicinity of IHSS 119.1 and the French Drain. Site utility maps will be consulted during the excavation and prior to laying the PVC pipe to ensure that the transmission line is not damaged. Standard health and safety practices will also be used to ensure that the transmission line remains intact.

All wastes generated as a result of this alternative will be managed in compliance with applicable regulations. They include spent GAC from the off gas treatment system and Building 891 water treatment system, regenerant solution from ion exchange resins in Building 891, treated soil, and wastes associated with installation of monitoring wells such as drill cuttings and decontamination water. The regenerant solution from the ion-exchange resins will be pH neutralized and sent to Building 374 for evaporation. Treated soil will be managed before final disposal in essentially the same manner as untreated soil and the spent GAC will be sent off site for regeneration.

The total remedial time frame for this alternative is 14 years. This includes three months for

a detailed soil gas survey three months for mobilization and demobilization nine months for excavation ten additional years of French Drain operation for plume remediation and three subsequent years of continued monitoring to ensure groundwater concentrations remain below PRGs A plan view of Alternative 7 is illustrated in Figure 3 9



EXPLANATION

- INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) AND IHSS DESIGNATION DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN
- ACTUAL CRAP METAL AND DRUM STORAGE AREAS IN IHSS 9 BASED ON AERIAL PHOTOGRAPH
- ACTUAL DRUM STORAGE AREA IN IHSS 113 BASED ON AERIAL PHOTOGRAPH
- B301889 ALLUVIAL WELL
- △ 0271 PRE 1986 WELL
- BH1587 BOREHOLE



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Plan View for
Alternative #5

Figure 3-9

OUT-EXC1.DWG

4 0 DETAILED ANALYSIS OF ALTERNATIVES

4 1 Description of Evaluation Criteria

This section analyzes the proposed remedial action alternatives using the criteria specified at 40 CFR 300.430 of the NCP and the *RCRA Corrective Action Plan* (CAP) (EPA 1994). Details of the alternatives presented in Section 3.0 are used as the basis for these analyses which address both the CERCLA criteria and RCRA standards. There are nine criteria designated in the NCP regulations and nine standards under the RCRA CAP guidance. The NCP and CERCLA guidance divides the criteria into threshold, balancing, and modifying criteria. Threshold criteria are statutory requirements that must be satisfied for an alternative to be eligible for selection. The two threshold criteria for this detailed analysis are overall protection of human health and the environment and compliance with ARARs.

The five primary balancing criteria are (1) long term effectiveness and permanence, (2) reduction in toxicity, mobility, and volume, (3) short term effectiveness, (4) implementability, and (5) cost. These are used to evaluate each alternative's major performance objectives. The relative performance of each alternative is evaluated and then compared to others to identify if any one alternative meets all the criteria.

The two modifying criteria, state acceptance and community acceptance, evaluate the feasibility of implementing an alternative in terms of its acceptance by regulatory agencies and the public. These criteria are not evaluated until after the formal public comment period on the CMS/FS report and proposed plan. The criteria are addressed in the CAD/ROD.

4 1 1 Overall Protection of Human Health and the Environment

Under CERCLA criterion and RCRA standards, each alternative is evaluated for the overall protectiveness of the proposed action. Proposed alternatives describe how human health and environmental risks are eliminated, reduced, or controlled through treatment engineering.

controls or institutional controls. The overall protection of human health and environment criteria is a threshold criteria which an alternative must meet to be the selected action. In particular, each alternative is required to be evaluated in meeting RAOs established for the site. The assessment also involves analyzing whether PRGs are satisfied through implementability, long term effectiveness and permanence, and short term effectiveness. The evaluation of overall protectiveness examines whether an alternative results in any unacceptable risks or cross media impacts to a site. The other threshold criteria is compliance with ARARs. Each alternative is required to be evaluated on the basis of how it complies with ARARs.

4.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

The selection of ARARs for an alternative is governed by the regulations of the NCP and EPA's Office of Solid Waste and Emergency Response (OSWER) Directives. Such directives include the *Compliance with Other Laws Manual* (EPA 1988b) and the RCRA CAP guidance. A discussion of the selection of chemical specific ARARs for OU 1 has been presented in Section 2. Briefly summarized, ARARs are:

- **Applicable** a requirement that applies under circumstances other than CERCLA to the contaminant, action, situation, or location, or
- **Relevant and appropriate** a requirement not normally applicable to the site but because the requirement addresses an activity, location, or situation similar to the site and the requirement is well suited to the remedial action proposed at the site, it is judged relevant and appropriate. It is possible for a requirement to be relevant but not appropriate for a site.

As remedial action alternatives are developed and screened through the CMS/FS process, environmental standards are further analyzed and screened for the site. Action specific and location specific ARARs previously identified in the OU 1 CMS/FS process have been further screened to check the jurisdictional and circumstantial ARAR prerequisites. Each identified standard has been noted as applicable, or relevant and appropriate, or not applicable, or relevant and appropriate for each alternative at OU 1. Any proposed standard or guidance which could be relevant to the circumstances at OU 1 was considered in the screening process. Proposed

standards and current guidance are described as TBCs in the detailed analyses. The criteria used to evaluate applicable requirements are

- Is the substance or contaminant addressed under the regulation
- Is the time period in the regulation applicable
- Does the regulation require limit or prohibit the activities
- Who is subject to the regulation
- Who is exempt from the regulation

The criteria used to evaluate relevant and appropriate requirements are

- The substance or contaminant addressed under the regulation is similar to the situation at OU 1
- The media affected by the requirement is similar to the circumstances at OU 1
- Activities affected by the regulation are similar to activities proposed at OU 1
- The area addressed by the regulation is similar to the area affected by the proposed alternative at OU 1
- Structures, facilities, or technologies addressed by the regulation are similar to those proposed at OU 1
- Exemptions or variances of a requirement are appropriate to the circumstances at OU 1

Each specific alternative is assessed to determine if the proposed action can comply with each identified ARAR or TBC. Section 121(d) of CERCLA requires remedial actions to comply with or exceed the ARARs designated at a site. It is a threshold criteria designated in the NCP regulations for proposing an alternative at a site. Compliance with applicable standards for waste management is also one of the criteria under the RCRA CAP guidance.

Compliance with an ARAR can be waived under specific circumstances as designated in CERCLA as amended [Section 121(d)(4)] and in the NCP regulations. Any proposed waivers from the ARARs are presented in the Proposed Plan and Record of Decision along with the

reasons for such an action. Reasons for a waiver include

- A State standard has not been consistently applied in similar circumstances
- The proposed action is an interim action
- Compliance with the ARAR will result in greater risk to human health and the environment than other alternative options
- Compliance is not technically feasible
- The selected action will attain a standard equivalent to an applicable standard using another approach

The RCRA CAP guidance does not include a specific method for obtaining waivers from ARAR compliance during a CMS. The Guideline does allow for some latitude in the establishment of media cleanup standards, however.

Media cleanup standards may be proposed by the permittee/respondent in the CMS Report based on promulgated federal and state standards, risk derived standards, site specific information and/or applicable guidance documents. Alternatively, standards may be set by the implementing agency prior to the CMS stage. If media cleanup standards are set by the implementing agency, the permittee/respondent may propose to modify them during the CMS. Final media cleanup standards will be determined by the implementing agency when the remedy is selected.

In addition to attaining the established media cleanup standards, potential remedies considered during the CMS process are required to comply with all applicable state or federal regulations.

State of Colorado Regulations allow for petitioning for the modification or waiving of RCRA regulations. General requirements for the petitioning process are found in 6 CCR 1007.3 Subpart C, Rulemaking Petitions. This section provides that any person may petition to modify or revoke any provision in Parts 260 through 265 of the Colorado Hazardous Waste Regulations. For example, wastes at a facility may be excluded from the list of hazardous wastes if the petitioner can demonstrate to the satisfaction of the CDPHE that the waste produced at the

facility does not meet any of the criteria under which the waste was listed as a hazardous waste. The results of the ARAR analysis conducted at OU 1 for each alternative is presented in a tabular form in Appendix D. Key ARARs selected from Appendix D for discussion in the detailed analysis of alternatives are those which are judged to be most critical to an alternative's implementation. Key ARARS include:

- Colorado Basic Standards for Groundwater 5 CCR 1002 8 3 11 5 and 3 11 6
- Colorado RCRA Regulations 6 CCR 1007 3 Parts 264 and 268 and proposed changes to Part 261
- Colorado Air Pollution Control Regulations 5 CCR 1001 5 Regulation 7
- Colorado Nongame Endangered or Threatened Species Conservation Act CRS 33 2 101

Key Applicable or Relevant and Appropriate Requirements

Since the State of Colorado is authorized by EPA to implement the RCRA program, the RCRA ARARs under the State program are designated as key ARARs. Releases and spills at OU 1 occurred prior to the effective date of the RCRA regulations so many of the RCRA regulations are designated relevant and appropriate rather than applicable to OU 1. The exception to this is the Colorado regulations regarding solid waste management units (SWMU) in 6 CCR 1007 3 264 90(a)(1) which are applicable to the circumstances at OU 1. They state that the owner or operator of constituents in SWMUs must comply with 264 101. Releases of hazardous constituents from SWMUs according to 264 101, Subpart F, require corrective action for protection of human health and the environment.

Subpart F of the Colorado RCRA regulations also concern groundwater protection. Many of the subsections of this subpart are directed to regulated units but OU 1 is not a regulated unit. However, OU 1 lists SWMUs in a RCRA Part B permit application inventory. Therefore, sections of Subpart F that are relevant and appropriate to OU 1 include:

- 6 CCR 1007 3 264 92 Groundwater protection standards
- 6 CCR 1007 3 264 93 Hazardous constituents
- 6 CCR 1007 3 264 94 Concentration limits
- 6 CCR 1007 3 264 95 Point of compliance
- 6 CCR 1007 3 264 96 Compliance period
- 6 CCR 1007 3 264 97 General groundwater monitoring requirements
- 6 CCR 1007 3 264 98 Detection monitoring program

These subsections are focused on the specifics of conducting a groundwater monitoring program and detecting exceedances of the groundwater protection standards

The other requirements of the Colorado RCRA program that are applicable to OU 1 are contained in 6 CCR 1007 3 264 101 This section requires that corrective actions be located between the SWMU and the downgradient facility boundary or beyond the facility boundary where necessary to protect human health and the environment unless specifically prohibited due to a lack of property ownership Onsite measures are determined on a case by case basis

Implementation of groundwater protection measures are also part of the Colorado Water Quality Control Commission's Basic Standards for Groundwater (5 CCR 1002 8 3 11 0) Since the Colorado State Basic Standards for Groundwater are potential chemical specific ARARs the implementation approach within the standards would be relevant and appropriate but not applicable CDPHE has implementation responsibility as detailed in 5 CCR 1002 8 3 11 6(B) The regulations of 5 CCR 1002 8 3 11 6(C) and (D) provide some discretion in the selection of the point of compliance Briefly summarized the point of compliance could be established at any one of the following locations

- The site boundary
- The hydrologically downgradient limit of the area in which contamination exists at the time identified
- At some distance hydrologically downgradient from the activity causing the contamination and closest to the activity as determined by site specific factors such as the established wellhead protection areas the potential of the site as an aquifer recharge area and the recommendations of the owner or operator

Another part of the Colorado RCRA regulations that are relevant and appropriate to OU 1 is the closure and post closure requirements for regulated units. The closure requirements of 6 CCR 1007 3 264 112 require preparation of a closure plan that is consistent with the requirements of the groundwater protection standards of Subpart F. Elements of the State post closure care requirements in 6 CCR 1007 3, 264 117 that are relevant and appropriate to OU 1 are the post closure care period and the requirements for maintenance and monitoring of waste containment systems in accordance with Subpart F. The post-closure period is 30 years after completion of remediation unless changed by CDPHE. Reasons for a reduced period include a demonstration that the groundwater protection standard has not been exceeded for a period of three consecutive years. In addition, it must be verified that the reduced time is protective of human health and the environment.

Air emission standards under the Colorado RCRA regulations (6 CCR 1007 3 264 1033 264 1052 264 1054 and 264 1057) and Regulation 7 of Colorado's Air Pollution Control Regulations are potentially applicable to the remediation alternatives that involve VOC emissions. Regulation 7 requires the use of reasonably available control technology (RACT) to control VOC emissions of over two tons/year or two lbs/hour.

Colorado's RCRA regulations require that VOC emissions from air stripping RCRA treatment units to be monitored and operated in accordance with the RCRA closed vent and control device system standards. The standards require condensers or adsorbers to achieve 95 percent weight efficiency and to institute exhaust vent stream monitoring [6 CCR 1007 3 264 1033(f) (g) or (h)]. Valves and equipment leaks are required to be monitored and maintained in a condition to achieve the no detectable emissions level.

The Colorado Nongame Endangered or Threatened Species Conservation Act (CRS 33 2 101 et seq) requires that indigenous species found to be endangered or threatened in Colorado be protected in order to maintain and enhance their numbers. It is a relevant and appropriate requirement for the OU 1 earth disturbing remediation alternatives. The Colorado Division of

Wildlife (CDOW) has the responsibility of determining management needs that will allow for the continued sustainability of populations of nongame species

The Colorado Nongame Endangered or Threatened Species Conservation Act is particularly significant to RFETS because it has the largest known population of Preble's meadow jumping mouse (*Zapus hudsonius ssp preblei*) in Colorado. The Preble's meadow jumping mouse is a species of special concern in Colorado. A special concern species is not legally protected but CDOW favors maintaining the species and enhancing its habitat where possible. Federal authorities currently consider the Preble's meadow jumping mouse a Category 2 species which is a candidate for listing as a Federal threatened or endangered species. Studies to gather information concerning the species and its need for Federal and State protection are ongoing. Should the mouse be listed on the Federal Endangered Species Act List, the requirements of Section 7 of the Act would be a key ARAR. Section 7 requires consultation with the U.S. Fish and Wildlife Service and in particular preparation of a biological assessment concerning the species and its habitat.

Habitat requirements for the Preble's meadow jumping mouse include intact riparian corridors such as those found along Woman Creek. There has been positive identification of Preble's meadow jumping mouse in riparian areas adjacent to the OU 1 boundary. As a Federal facility, it is the obligation of the operator of RFETS to minimize the impact of remediation to riparian areas. RFETS staff will coordinate activities with CDOW to ensure that the population of Preble's meadow jumping mouse at RFETS is protected to the extent possible during implementation of the selected alternative at OU 1.

4.1.3 Long Term Effectiveness and Permanence

One of the balancing criteria listed in the NCP is long term effectiveness and permanence. In the CAP guidance, it is listed as long term reliability and effectiveness. Each alternative is also required to be evaluated against this criteria. The NCP emphasizes the preference for treatment to achieve long term protection and permanence for a site. RCRA CAP guidance also

emphasizes long term reliability and effectiveness as a factor in selecting a proposed alternative
Criteria for evaluating long term effectiveness and permanence include the following

- Persistence toxicity and mobility of hazardous substances and their constituents and their tendency to bioaccumulate
- Long term uncertainties associated with containment
- Long term potential for adverse health effects
- Long term cost of monitoring and maintenance
- Ease of undertaking future remedial action

Considerations are focused on the residual risk remaining after implementation of the alternative
In particular the evaluation of the alternative is to consider whether RAOs will be met RAOs often are focused on long term effectiveness and permanence The evaluation of a proposed alternative must include an analysis of the potential threat to human health and the environment from untreated waste or treatment residuals remaining at the site after remediation This analytical process includes the following elements

- Volume and concentration of contaminants in untreated media
- Volume and concentration of contaminants in treated residuals
- Requirements for 5 year site reviews and long term monitoring
- Difficulties associated with long term operations and maintenance
- Adequacy and reliability of controls
- Potential need to replace technical components
- Potential exposure pathways and risks posed should the remedial action need replacement

4 1 4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Another one of the balancing criteria in the NCP and RCRA CAP guidance is reduction of toxicity mobility or volume of wastes through treatment. The CERCLA criterion evaluates the ability of an alternative to reduce the risks at a site through the destruction of toxic contaminants, reduction of the mass of toxic contaminants, reduction in contaminant mobility, and reduction of the volume of contaminated media. The NCP states a preference for remedial alternatives that include treatment which achieves this criterion as a principal element of the remedy. RCRA CAP guidance also specifies reduction in the toxicity mobility or volume of waste as a standard for the selection of a preferred alternative. Specific considerations for reduction of toxicity mobility or volume (TMV) include the following:

- Adequacy of the treatment process to address PRGs
- Specific requirements and limitations of the treatment process
- Volume of the contaminated media treated
- Extent of TMV reduction
- Irreversibility of treatment
- Quantities and toxic characteristics of treatment residuals or byproducts

4 1 5 Short Term Effectiveness

Short term effectiveness is another of the NCP balancing criteria and a standard of the RCRA CAP guidance. In evaluating alternatives, the CERCLA criterion and RCRA standards relevant to short term effectiveness consider the period of time required for construction and implementation of each alternative. The criterion evaluates community and worker protection during the remediation activity as well as potential adverse environmental impacts that may result from the alternative. The consideration of environmental impacts during remediation includes elements as an evaluation of the impact of the alternatives on the quality of habitat at the site.

4 1 6 Implementability

Implementability is a criteria under both the NCP regulations and RCRA CAP guidance. This

criterion addresses the technical and administrative feasibility of implementing an alternative including the availability of materials and services. Implementability is particularly important for evaluating the reliability of technologies that are innovative or proprietary. Specific considerations relevant to implementability include the following:

- Ability to construct and operate the alternative within a 10 to 30 year time frame
- Availability of equipment and specialists
- Availability and reliability of the components of the alternative
- Ability to monitor the effectiveness of the alternative
- Demonstrated performance level of the treatment components and equipment
- Difficulty in implementing future remedial actions once the alternative is in place

The RCRA implementability standard also requires addressing these same considerations for each alternative. The implementability evaluation is required to identify the administrative and coordinated local, State, and federal requirements. The CAP guidance requires identification of necessary permits.

4.1.7 Cost

Cost is a criterion under the NCP regulations and RCRA CAP guidance. It is one of the balancing criteria under the NCP. Cost is to be evaluated via the capital costs, long term operation and maintenance (O&M) costs, and post closure costs. Present worth costs are used to compare expenses of each alternative that occur over different time periods. By discounting all costs to a common base year, the cost of each alternative can be reduced to a single figure for comparative analysis. This report assumes a discount interest rate of 5 percent (as specified in the CMS/FS guidance) to calculate the present worth of each alternative. In addition, a maximum implementation period of 30 years has been used for alternative analysis.

Cost can be significantly different from one alternative to another and may be the major difference in providing equivalent long term effectiveness and permanence. An alternative with an excessive cost when compared to overall effectiveness may not be feasible as a preferred alternative. Also, an alternative with a low initial capital cost may have a larger total cost when

O&M is considered. Higher costs may be offset by improved performance or greater long term risk reduction in the comparative analysis of alternatives. However, the alternative that satisfies the CERCLA requirements in the most cost effective manner is selected as the preferred alternative.

4.1.8 State Acceptance

State (and community) acceptance of the proposed preferred alternative are modifying criteria according to the NCP regulations and the RCRA CAP guidance on public involvement. Changes to the proposed corrective measures may be made after consideration of public comments and a determination by CDPHE that changes are necessary to the preferred alternative. State acceptance refers to CDPHE's or other state agencies' comments on the appropriateness of the proposed preferred alternative. CDPHE's concerns about the preferred alternative and other alternatives are to be assessed as early in the regulatory process as practicable, usually in the remedial action plan/proposed plan. The State's comments on ARARs or proposed use of waivers are to be addressed by the lead agency.

4.1.9 Community Acceptance

The community acceptance criteria/public involvement policy of the NCP regulations and RCRA CAP guidance is the last criteria to be evaluated prior to final selection of a remedy. The DOE, EPA, and the State will evaluate the issues and concerns raised by the public in their comments on the proposed remedial action plan/proposed plan. Interested people or groups in the community may support, have reservations about, or oppose some components of the preferred alternative. Their concerns may influence the final selection of an alternative in the CAD/ROD.

4.2 Background Analyses

Background analyses have been conducted to obtain data to assist in the detailed analysis of alternatives including establishing groundwater monitoring requirements, groundwater modeling,

and residual risk assessment Each of these analyses are described in the following subsections

4 2 1 Groundwater Monitoring

Groundwater monitoring is included as part of each alternative presented in this report For the purposes of the detailed analysis of alternatives it is assumed that a performance monitoring system would be used to comply with the RCRA regulations New wells would be installed including one deep cluster and one shallow well cluster downgradient of IHSS 119 1 and possibly two additional wells upgradient of Woman Creek It is suggested that installation of the well clusters be preceded by geological and geophysical support such as photographic lineament analysis or three-dimensional seismic surveys This would enable paleochannels and faulted zones to be clearly identified prior to the well installations

Samples would also be collected semiannually from the French Drain Samples would be analyzed for organic and inorganic contaminants including individual species of inorganic contaminants to identify individual metal species with a potential to bioaccumulate This additional analysis should not be a routine component of the sampling program

4 2 2 Groundwater Modeling

Groundwater modeling has been performed to support the detailed analysis of the alternatives Groundwater modeling was completed to predict downgradient contaminant concentrations resulting from suspected DNAPL sources at IHSS 119 1 Three conceptual models were identified and used to predict future contaminant concentrations at the downgradient side of the French Drain and in the alluvium of Woman Creek (Alternative 0) The No Action model was used to examine contaminant migration patterns with no source removal and decommissioning the French Drain The Institutional Controls model (Alternative 1) was used to examine contaminant migration patterns with the French Drain and extraction well in operation The remediation model (Alternatives 3 4 and 5) was used to examine the effect of remediating the suspected sources within IHSS 119 1 to the PRGs and to predict downgradient concentrations

once this goal was achieved. Based on the modeling results, the historic use of the site, and the sporadic nature of the observed contamination, it is assumed that the contamination occurred because of small episodic spills and that large pools of DNAPL do not exist.

The model is considered to be conservative (i.e., overpredicts contaminant concentrations) because

It is two dimensional and does not simulate dispersion transverse to the plane of the model. Therefore, the concentrations are consistently overestimated by the model.

The model assumes a constant groundwater flow when the site frequently has periods of either low flow or no flow.

The model converged well with actual conditions at the site as indicated by

Convergence with observed hydraulic conductivities and groundwater flow rate and direction. It indicates that the advective transport rates of the model are similar to actual conditions.

Simulation of the observed sporadic nature of the contaminant concentrations. The sporadic nature indicates that the source is intermittent; as the groundwater table rises, it contacts the residual DNAPL in the subsurface soil, which results in some partitioning to the groundwater.

Accurate prediction of the effects of the French Drain and the extraction well on the hydrologic system at the site.

In general, the results of the model indicated that

Contaminant concentrations are always overpredicted by the model. The implications of this are: (1) estimated exposure concentrations are conservative because they bound observed concentrations; (2) alternate source locations and conditions (such as a source located somewhere outside the plane of the model or a source with a different release mechanism such as diffusion from fractures in bedrock) are indirectly accounted for by the model; a different source is unlikely to result in higher predicted concentrations; (3) spreading of a source caused by degradation and subsequent generation of a contaminant along a

flowpath is also accounted for by the model because the estimated concentrations are much higher than actually observed (4) predictive simulations overestimate contaminant concentrations because they are based on the same concepts as the calibrated model and (5) if the model was more realistic the simulated concentrations would be smaller and more consistent with observed data which would translate into smaller concentrations under the predictive simulations

The model simulates relatively well the oscillatory behavior observed in actual concentrations This supports the concept that the source periodically releases solutes and that the timing is related to seasonal variations in climatic conditions

The model accurately predicts the effects of the French Drain and the extraction well The rise in simulated 1,1-DCE and 1,1,1-TCA concentrations in Figures B-27 and B-25 respectively that occur around 1992 is caused by simulating the operation of the French Drain which started construction in November 1991 and finished in April 1992 The rise in concentrations is caused by the increased hydraulic gradient resulting from the installation and operation of the French Drain which pulls groundwater more rapidly towards Well 0487 The simulated concentrations begin decreasing around 1993 when the extraction well started operating The gradients are reduced when the extraction well is simulated because it pulls groundwater away from Well 0487 The observed concentrations vary in the same manner The similarity between the model and observed variations in concentrations leads to the conclusion that the observed variations are caused by the installation and operation of the French Drain and extraction well That the model simulates this behavior underscores the conclusion that the model is an accurate and adequate representation of site conditions The spiking effect caused by the French Drain is observed in all contaminants

Sensitivity analyses were completed for porosity decay rate, adsorption and hydraulic conductivity The sensitivity shown for adsorption decreased with time as the effect of the decay rate increased on the contaminant concentrations The analysis for porosity also indicated an overriding effect of decay as time progressed Hydraulic conductivity was consistently the most sensitive parameter chosen for the analyses and should affect transport rates and dispersion Therefore the hierarchy of sensitivity for the parameters chosen for the analyses is

Hydraulic Conductivity >>>> Decay >> Porosity and Adsorption

Because the model converged well with observed hydraulic conductivities it was assumed that

the model was calibrated well with the actual hydrologic system

The computer simulation code TARGET_2DU (Dames & Moore 1985) was used to simulate contaminant transport in the subsurface at OU 1. TARGET_2DU is a vertically oriented finite difference model that can simulate variably saturated conditions. This model was selected due to the variability of the saturated zone at OU 1 and because it has been successfully applied at other Superfund sites to support final CADs/RODs. Detailed assumptions and uncertainties associated with the model are included in Appendix B. The model will be available for public use in 1995.

In examining the results of the modeling effort, PCE, TCE, DCE, TCA, and CCl_4 were selected as contaminants at the site. A list of the peak concentrations predicted for the contaminants at the French Drain and Woman Creek for each alternative is found in Table 4.1.

For the No Action Alternative, concentrations rise and then remain constant for the remainder of the modeling period. For the Institutional Controls with the French Drain Alternative, the peak concentrations occur at the beginning of the model. They continue to decrease with time. For the remediation alternatives, Alternatives 2 through 5, concentrations rise for a short time then decrease for the remainder of the modeled period.

The three conceptual models were also used to estimate residual risk levels associated with the remedial action alternatives proposed in this section.

4.2.3 Residual Risk Assessment

The residual risk assessment presented in Appendix C documents the approach and calculations used to estimate risks associated with the proposed alternatives. To select the most appropriate pathways and contaminants, the results of the OU 1 PHE were reviewed.

Groundwater modeling was performed to estimate the contaminant concentrations in

groundwater using the three conceptual models for OU 1. The results were then compared to contaminant specific PRGs for OU 1. Using these results from groundwater modeling noncarcinogenic hazard indices and carcinogenic risks were calculated. The results indicate that none of the calculated noncarcinogenic hazard indices approach 1 and that the maximum calculated carcinogenic risk 1.2×10^{-5} is for the No Action scenario. The acceptable carcinogenic risk range is 10^{-4} to 10^{-6} . Noncarcinogenic hazards greater than 1 can indicate a potential for adverse effects to human health. The carcinogenic risks and noncarcinogenic hazards for each alternative are listed in Table 4.1.

4.3 Detailed Analysis of Alternatives

The detailed analysis of alternatives evaluates the two threshold and five balancing criteria for each alternative. The analysis is conducted at a level of detail that builds on the information presented in Section 3 and is sufficient to provide an understanding of each alternative. Any uncertainties associated with the evaluation are also identified in the detailed analysis. Key trade-offs, with respect to the criteria, are identified for the alternatives. According to the CMS/FS guidance, the results of the detailed analysis are designed to provide the basis for identifying a preferred alternative for the remedial action.

Assumptions used in performing the detailed analysis of alternatives include the following:

- DNAPLs are potentially present in the subsurface soil at IHSS 119.1 based on the results of the Phase III RFI/RI report. If present, it is assumed that they are primarily in residual form and in small quantities.
- Groundwater monitoring proposed under each alternative will include sampling and analysis at the French Drain sump and potentially a new performance monitoring system at OU 1. The locations would be sampled semiannually and analyzed for both organic and inorganic contaminants.
- A soil gas survey will be conducted prior to initiating any of the proposed treatment actions to more accurately define areas at OU 1 that require treatment. For purposes of the detailed analysis, a 100 ft x 100 ft x 20 ft area located at the drum storage at IHSS 119.1 is used for the treatment area.

Table 4-1
Predicted Peak Contaminant Concentrations and Human Health Risks

Alternative	Performance Monitoring Location	
	Downgradient of French Drain	Upgradient of Woman Creek ^a
Alternative 0 No Action		
Predicted Peak Concentrations $\mu\text{g}/\ell^b$		
PCE	10	5 7E-02
TCE	1 050	44
1 1 DCE	0 22	3 1E-06
1 1 1 TCA	38	1 0E-01
CCl ₄	1 8	7 7E-04
Carcinogenic Risk ^d		
Resident	1 2E-05	3 3E-08
Worker	9 2E 12	3 1E 15
Noncarcinogenic Hazard Index ^e		
Resident	0 14	2 4E-04
Worker	1 1E-08	2 5E 11
Alternative 1 Institutional Controls with the French Drain		
Predicted Peak Concentrations $\mu\text{g}/\ell^b$		
PCE	2 0	3 1E-02
TCE	420	23
1 1 DCE	1 8E-03	1 4E-07
1 1 1 TCA	5 2	4 8E-02
CCl ₄	0 12	2 3E-04
Carcinogenic Risk ^d		
Resident	3 3E-07	3 5E-09
Worker	6 1E 14	2 4E 16
Noncarcinogenic Hazard Index ^e		
Resident	2 9E-03	2 3E-05
Worker	3 0E 10	1 8E 12

**Table 4-1
(Continued)**

Alternative	Performance Monitoring Location	
	Downgradient of	Upgradient of
Predicted Peak Concentrations $\mu\text{g}/\ell^b$		
PCE	6 5	3 2E-02
TCE	820	31
1 1 DCE	0 22	3 1E-06
1 1 1 TCA	23	4 8E-02
CCl_4	1 8	7 7E-06
Carcinogenic Risk^d		
Resident	6 7E-07	1 2E-08
Worker	9 8E 14	1 0E 15
Noncarcinogenic Hazard Index^e		
Resident	5 6E-03	8 2E-05
Worker	5 0E 10	6 5E 12
Alternative 3 Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement		
Predicted Peak Concentrations $\mu\text{g}/\ell^b$		
PCE	6 5	3 2E-02
TCE	820	31
1 1 DCE	0 22	3 1E-06
1 1 1 TCA	23	4 8E-02
CCl_4	1 8	7 7E-06
Carcinogenic Risk^d		
Resident	6 7E-07	1 2E-08
Worker	9 8E 14	1 0E 15
Noncarcinogenic Hazard Index^e		
Resident	5 6E-03	8 2E-05
Worker	5 0E 10	6 5E 12

**Table 4-1
(Continued)**

Alternative	Performance Monitoring Location	
	Downgradient of	Upgradient of
Alternative 4 Hot Air Injection with Mechanical Mixing		
Predicted Peak Concentrations $\mu\text{g}/\ell^b$		
PCE	6 5	3 2E-02
TCE	820	31
1 1 DCE	0 22	3 1E-06
1 1 1 TCA	23	4 8E-02
CCl_4	1 8	7 7E-06
Carcinogenic Risk ^d		
Resident	6 7E-07	1 2E-08
Worker	9 8E 14	1 0E 15
Noncarcinogenic Hazard Index ^e		
Resident	5 6E-03	8 2E-05
Worker	5 0E 10	6 5E 12
Alternative 5 Soil Excavation with Groundwater Pumping		
Predicted Peak Concentrations $\mu\text{g}/\ell^b$		
PCE	6 5	3 2E-02
TCE	820	31
1 1 DCE	0 22	3 1E-06
1 1 1 TCA	23	4 8E-02
CCl_4	1 8	7 7E-06
Carcinogenic Risk ^d		
Resident	6 7E-07	1 2E-08
Worker	9 8E 14	1 0E 15
Noncarcinogenic Hazard Index ^e		
Resident	5 6E-03	8 2E-05
Worker	5 0E 10	6 5E 12

Actual peak concentrations should be less than modeled concentrations since operation of the French Drain was not included in the groundwater model under remediation scenarios

^b Predicted by groundwater model TARGET_2DU (Dames & Moore 1985)

PRGs are PCE 5 $\mu\text{g}/\ell$ TCE 5 $\mu\text{g}/\ell$ 1 1 DCE 7 $\mu\text{g}/\ell$ 1 1 1 TCA 200 $\mu\text{g}/\ell$ and CCl_4 1 $\mu\text{g}/\ell$

^d Acceptable risk range is 10^{-4} to 10^{-6} per the NCP

Hazard index greater than 1 indicates a potential for adverse human health effects

In the comparative analysis, a qualitative sensitivity analysis is performed to assess the major assumptions which if incorrect could significantly impact the results of the detailed analysis of the alternatives

This section documents the detailed analysis of the proposed alternatives in the following subsections

- Alternative 0 No Action
- Alternative 1 Institutional Controls with the French Drain
- Alternative 2 Groundwater Pumping and Soil Vapor Extraction
- Alternative 3 Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement
- Alternative 4 Hot Air Injection with Mechanical Mixing
- Alternative 5 Soil Excavation with Groundwater Pumping

4 3 1 Alternative 0. No Action

The evaluation of the two threshold and five balancing criteria for Alternative 0 No Action is summarized in the following subsections

4 3 1 1 Overall Protection of Human Health and the Environment

The degree of protection for human health and the environment is not increased from the current conditions under the No Action Alternative. Similarly, the exposure potential is not decreased by the alternative. It relies on natural degradation processes such as dispersion, volatilization, and biodegradation to gradually reduce contaminant concentrations so the time for the site to undergo full remediation by natural degradation is difficult to predict.

Chemical specific ARARs are currently not in compliance with the State groundwater standards

according to groundwater monitoring results Under the No Action Alternative the site would remain noncompliant with the State s Basic Groundwater Standards (5 CCR 1002 8 3 11 5) according to modelled conditions In addition the RCRA CAP criteria for controlling contamination is not satisfied by the alternative This alternative may provide long term effectiveness primarily because the natural degradation processes are essentially irreversible There are conditions that can exist however that allow the byproduct or endproduct of a degradation process to be more hazardous to the environment and human health than the original contaminant In addition conditions at the site may allow some of the degradation process to reverse or remain in flux

Groundwater modeling indicates that the carcinogenic risk at the downgradient side of the French Drain is below the acceptable risk range of 10^{-4} to 10^{-6} The carcinogenic risk at the alluvium of Woman Creek is within the acceptable risk range The noncarcinogenic hazard indices for the French Drain and Woman Creek do not indicate a potential for adverse effects to human health Because the current site conditions do not change there are no increases in potential risks to the public workers or the environment under the No Action Alternative It is assumed that current health and safety practices will continue to protect workers and visitors to the site

4 3 1 2 Compliance With Applicable or Relevant and Appropriate Requirements

Three types of ARARs chemical specific action specific and location specific are evaluated for each alternative The following sections evaluate the key ARARs specific to this alternative

Chemical Specific ARARs

The results of groundwater monitoring from 1989 1994 indicate that the State Basic Standards for Groundwater (5 CCR 1002 8 3 11 5) are currently exceeded beneath OU 1 Specific chemical concentrations which exceed standards are CCl_4 1 2 DCA 1 1 DCE 1 2 DCE(cis) DCE 1 1 1 TCA and TCE

Review of the groundwater modeling results of the chemicals present beneath OU 1 from 1969 to 2029 and the hydrogeological conditions indicate that the peak concentrations of contaminants probably would not comply with the State Basic Standards for Groundwater at the French Drain. Peak concentrations of contaminants at Woman Creek except for TCE probably would comply with the State Basic Standards for Groundwater. Results of the modeling also indicate that the concentrations of TCE at the French Drain may exceed the State Groundwater Standards beyond the year 2029 the limit of the groundwater model. The results of the model reflect the high solubility of TCE in water and a steady state modelled flow of groundwater conditions. Assumptions of the model include a continuous source of groundwater contamination without the French Drain operating nor implementation of any other remediation technology. Explanation of the model and further discussions of the results of modeling are in Appendix B.

Action Specific ARARs

Since contaminants would be left in place at the IHSSs at OU 1, a plan to monitor contaminants would be required at the time of closure. A RCRA performance monitoring system would be implemented with this alternative for 30 years or more. Monitoring of the organic and inorganic constituents would be conducted in accordance with Subpart F of the State RCRA regulations (6 CCR 1007.3.264.93.264.98). Monitoring would be conducted until it is determined that the contaminants are in compliance with the State Basic Standards for Groundwater (5 CCR 1002.8.3.11.5). The state groundwater standards for the contaminants are selected for monitoring since the RCRA regulations do not have protection standards for the contaminants except for selenium.

Corrective action would only be monitoring for as long as necessary to achieve the state groundwater standards at the selected point of compliance. Maintenance and monitoring of constituents would be required to be conducted for more than 30 years based on modeling results. The performance monitoring system would operate until there is no exceedances of groundwater standards for three consecutive years. The post closure period would be

determined by the time it takes for natural degradation and dispersion of contaminants. Implementation of this alternative would require a determination by CDPHE that the corrective action is protective of human health and the environment. Such a determination is not likely since this alternative would not meet RAOs. In addition, a point of compliance for the performance monitoring systems would need to be selected to demonstrate compliance with the RCRA corrective action requirements and the ground water protection standard (Subpart F).

There would not be any air emissions associated with this alternative; therefore, the RCRA and air pollution control program regulations are not ARARs.

Location Specific ARARs

Alternative 0 would comply with the laws and regulations specific to wetlands and threatened and endangered or species of special concern. When the French Drain is decommissioned, the wetland and riparian habitat may temporarily decrease in size. The anticipated long term effect is a net gain in wetland acreage. The CDOW will be consulted for advice on mitigation measures to lessen the effects of the French Drain decommissioning.

4.3.1.3 Long Term Effectiveness and Permanence

The No Action Alternative involves groundwater monitoring for 30 years. This alternative should not provide additional protection for human health, the environment, and ecological receptors because operation of the French Drain, which currently appears to be effective in capturing contaminated groundwater, would be discontinued under this alternative.

Groundwater modeling indicates that the No Action Alternative's carcinogenic risks at the French Drain and Woman Creek are within or below the acceptable risk range of 10^{-4} to 10^{-6} . The noncarcinogenic hazard indices for the French Drain and Woman Creek do not indicate a potential for adverse effects to human health.

The alternative does not address treatment of the source nor does it control the source. The French Drain would not be operational and there is a possibility that contaminated groundwater may migrate from OU 1. Five year reviews would be required to determine the effectiveness of this alternative until the contaminant concentrations are consistently below the PRGs and the agencies agree that the site is not a cause for concern.

4.3.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The No Action Alternative will not satisfy the NCP preference for treatment as a principal element of an alternative. It does not treat groundwater and subsurface soil nor does it control the primary contaminant source. Similarly, no wastes are created as a result of this alternative except for wastes created during well installation such as decontamination water and drill cuttings.

The No Action Alternative reduces the toxicity, mobility, or volume of contaminants only through natural degradative processes such as volatilization. The remediation time for natural degradation may be long even with low initial contaminant concentrations; however, it is assumed for this alternative that groundwater monitoring will be required for at least 30 years.

4.3.1.5 Short Term Effectiveness

The No Action Alternative does not offer any additional protection for human health and the environment. Because no remedial actions are implemented, there are no additional short term risks to the local community, workers, ecological receptors, or the environment. Existing health and safety procedures at the site are assumed to offer effective protection for workers and

visitors Adherence to appropriate health and safety measures will be required for as long as monitoring activities are continued at OU 1

4 3 1 6 Implementability

The No Action Alternative is easily implemented because its only component is long term groundwater monitoring and the installation of a performance monitoring system It should not be limited by the availability of services and materials nor are there any significant technical or administrative difficulties associated with this alternative

Normally natural degradative processes are irreversible and result in compounds that are less hazardous than the original compounds There are conditions that can exist, however that allow the byproduct or endproduct of a degradative process to be more hazardous to the environment and human health than the original contaminant In addition conditions at the site may allow some of the degradative process to reverse or remain in flux

4 3 1 7 Cost

Capital costs associated with the No Action Alternative include the completion of four groundwater monitoring wells and post closure costs consist of groundwater monitoring for 30 years There are no O&M costs anticipated for this alternative Total capital cost of this alternative is \$63 800 and the post closure expenditures total \$1 740 400 The total cost for this alternative is \$1,804 200 A detailed cost estimate is included in Appendix A

4 3 2 Alternative 1. Institutional Controls with the French Drain

The evaluation of the two threshold and five balancing criteria for Alternative 1 Institutional Controls with the French Drain is summarized in the following subsections

4 3 2 1 Overall Protection of Human Health and the Environment

Alternative 1 will be protective of human health and the environment assuming that the institutional controls are properly implemented the French Drain and Building 891 water treatment system continue operation and the site is not abandoned during the institutional control period The potential for exposure is reduced by removing contaminated groundwater at the French Drain Other institutional controls may include restrictions on well construction well installation zoning, and property transfers

The French Drain would capture contaminated groundwater for treatment thereby preventing potential downgradient migration of contaminants The alternative does not involve significant disturbance of the site so short term risks will be minimized for workers and the environment It is assumed that standard health and safety procedures will be sufficient to protect on site workers and visitors Compliance with action specific ARARs can be achieved with this alternative as the area of disturbance is minimal for decommissioning the French Drain

Chemical specific ARARs can be met using the French Drain and institutional controls Modeling indicates that State groundwater standards (the PRGs) would be met with the possible exception of TCE at Woman Creek and the French Drain Natural degradation is expected to be a factor in long term effectiveness and compliance with the ARARs because of the low contaminant concentrations at IHSS 119 1 The institutional controls are also a factor in determining the long term effectiveness of this alternative

Alternative 1 meets the RCRA CAP criteria for attaining groundwater cleanup standards for all of the contaminants with the possible exception of TCE TCE concentrations at the French Drain do not meet the groundwater PRGs during the modeling time frame and may not meet them until the source of contamination is depleted

Carcinogenic risks at the French Drain and Woman Creek are below the acceptable range of 10^{-4} to 10^{-6} The noncarcinogenic hazard indices for the French Drain and Woman Creek do not

indicate a potential for adverse effects to human health

In Alternative 1 DNAPL contamination is controlled by passive containment and collection of groundwater rather than active remediation. This type of action is usually well suited to sites such as OU 1 that have low aquifer transmissivity, low projected groundwater use, and low initial contaminant concentrations.

Reduction in contaminant concentrations at the primary contaminant source and in groundwater should occur over time. The actual remediation time is dependent on the locations and volumes of the DNAPL contamination which are not certain at this time. Therefore, groundwater monitoring will be used to determine when the primary contaminant source is no longer considered an issue.

4.3.2.2 Compliance With Applicable or Relevant and Appropriate Requirements

Three types of ARARs: chemical specific, action specific, and location specific, were evaluated for this alternative. The following sections discuss the key ARARs specific to this alternative.

Chemical Specific ARARs

The results of groundwater monitoring from 1989-1994 indicate that the State Basic Standards for Groundwater (5 CCR 1002.8.3.11.5) are currently exceeded at OU 1. Contaminants which exceed the standards are PCE, TCE, 1,1-DCE, 1,2-DCA, 1,2-DCE(cis), CCl_4 , and 1,1,1-TCA.

Concentrations at the French Drain and Woman Creek were modeled to determine if Alternative 1 would comply with the ARARs. Review of the groundwater modeling results from 1969-2029 indicates that in all probability the concentrations of contaminants will be reduced to below the Basic Standards for Groundwater (5 CCR 1002.8.3.11.5). According to the modeling results, TCE, CCl_4 , DCE, 1,1-DCE, and 1,1,1-TCA would comply with the state groundwater standards by the year 2010 at the Woman Creek location. In addition, the organic contaminant

concentrations would likely comply with the State Basic Standards for Groundwater at the French Drain. Although the peak concentrations of TCE remain above the TCE groundwater standard according to the modeling results, the model conservatively assumes an infinite source. Peak concentrations of TCE would in all probability be collected by the French Drain and treatment system and be reduced with time to below the groundwater standard. Assumptions of the model and discussion of results are in Appendix B.

Action Specific ARARs

The French Drain will collect contaminated groundwater for treatment for as long as is necessary to consistently achieve the State groundwater standards. However, some contamination may be left due to the uncertainty of the location and volume of the contaminants, the sporadic nature of groundwater movement, and the climatic conditions at OU 1.

Compliance with 6 CCR 1007.3.264.90 and 264.101 of the State RCRA program is required at OU 1. Since some contaminants would be left in place, a plan to monitor contaminants would be required at the time of closure. A RCRA performance monitoring system would be implemented with this alternative for as long as is necessary to demonstrate compliance with the state groundwater standards at the selected point of compliance. Monitoring of the organic and inorganic constituents would be conducted in accordance with Subpart F of the State RCRA regulations (6 CCR 1007.3.264.93, 264.98). A post closure period of 30 years would be initiated with CDPHE. The State Basic Standards for Groundwater (5 CCR 1002.8.3.11.5) are identified as the monitoring levels since the RCRA regulations do not have the organic contaminants listed in the groundwater protection standards of 40 CFR 264.94.

Corrective action would be conducted as long as necessary to achieve the state groundwater standards at the selected point of compliance. Maintenance and monitoring of constituents is required until the performance monitoring system indicates no exceedances of the groundwater standards for three consecutive years. The period to achieve compliance depends on the effectiveness of the water treatment system as well as natural degradation. Implementation of

this alternative would require a determination by CDPHE that the corrective action is protective of human health and the environment. In addition, a point of compliance for the performance monitoring system would need to be selected to demonstrate compliance with the RCRA corrective action requirements and the groundwater protection standard (Subpart F).

Other action specific ARARS such as the Colorado Water Quality Control Act effluent limitations for the water treatment system would be complied with during operation of the system.

The State air pollution regulations and RCRA hazardous air pollutant standards would not be an ARAR for this alternative since there are not technologies or facilities which could be a source of emissions.

Location Specific ARARs

Alternative 1 would undergo a significant disruption when the French Drain is scheduled for decommissioning. Decommissioning the French Drain will temporarily disturb wetlands and riparian areas around the drain. The short term effect of the decommission may be a loss of wetland acreage but the long term effect is expected to be a net gain in wetland acreage. Mitigation measures will be used to minimize the impacts and to comply with regulations on wetland protection and threatened and endangered or species of special concern.

4.3.2.3 Long Term Effectiveness and Permanence

Under this alternative, the French Drain removes contaminated groundwater migrating from IHSS 119.1, the area south of Building 881, and the western portion of IHSS 119.2. It is expected that natural degradation will be a significant factor in ensuring long term effectiveness for this alternative because of the low contaminant concentrations. Groundwater monitoring will be conducted at the site until the contaminant concentrations are consistently below the PRGs and the agencies agree that the site is no longer a cause for concern. For the purposes of this

detailed analysis, the period for groundwater monitoring is 30 years. Every 5 years a review will be conducted at the site to determine the alternative's effectiveness and degree of permanence.

Human health risks may be reduced at the site by restricting access to wells at the site and prohibiting construction in the area. The alternative can provide some long term protection for human health and the environment provided the institutional controls remain in place. Carcinogenic risks at the French Drain and Woman Creek are below the acceptable risk range of 10^{-4} to 10^{-6} . The noncarcinogenic hazard indices for the French Drain and Woman Creek do not indicate a potential for adverse effects to human health.

The French Drain passively collects groundwater rather than actively remediating the site. The theory behind the alternative is that groundwater containment should adequately protect human health and the environment. The theory is corroborated for the contaminants by the groundwater model with the possible exception of TCE and the human health risk calculations. The model indicates that groundwater should meet the PRGs for the contaminants at Woman Creek with the possible exception of TCE. Because of the uncertainty regarding the location and volume of the primary contaminant source, groundwater collection and treatment should continue until the groundwater consistently meets the PRGs to increase the degree of permanence achieved by the alternative.

Wastes generated as a result of this alternative will be managed according to applicable regulations. Waste types include spent GAC and regenerant solutions from ion-exchange resins. Regenerant solution will be treated in the Building 891 water treatment system by pH neutralization and evaporation in Building 374. The spent GAC will be sent offsite for regeneration. There are no significant risks associated with handling the ion exchange resins or shipping the spent GAC.

4 3 2 4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 1 does not actively remediate the primary source of contamination. However, operation of the French Drain will reduce the mobility and volume of contaminants in groundwater at OU 1. Contaminant toxicity will be reduced when the groundwater is treated by UV/Peroxide in the Building 891 water treatment system.

The Building 891 treatment system currently operates with high removal efficiencies for all of the contaminants except for CCl_4 . It is expected that the GAC unit from OU 2 will be added to the Building 891 water treatment system and this modification will make it possible for the system to effectively treat CCl_4 . Wastes generated from this alternative include regenerant solution from ion exchange resins and spent GAC which is sent offsite for regeneration. The regenerant solution is transferred to the Building 891 water treatment system for pH neutralization and sent to Building 374 for evaporation.

Contaminant removal through groundwater extraction is irreversible, however, contamination in soil at IHSS 119.1 may continue to contaminate groundwater through infiltration. Degradation and/or removal of the contaminants should eventually be achieved but may require an extended period of time.

4 3 2 5 Short Term Effectiveness

Protection of human health and the environment should not increase under this alternative because it does not change the processes already in place at the site. The components of Alternative 1, institutional controls and operation of the French Drain, should not incur additional risks to the public, on-site workers, ecological receptors, or the environment. Existing safety measures used for permanent workers and visitors should offer effective and reliable protection at OU 1. Adherence to appropriate health and safety measures will be required for as long as monitoring activities are continued at OU 1.

The impact at Woman Creek is minimal and does not represent a departure from the current impacts under the IM/IRA. The groundwater model indicates that surface water standards for Woman Creek should be met for all of the contaminants with the possible exception of TCE. However, risk based calculations indicate that the carcinogenic risk and noncarcinogenic hazard are below the acceptable limits.

4.3.2.6 Implementability

Alternative 1 should not limit the options for future remediation if it is deemed necessary. It is easily implemented because the only addition to current site conditions is the implementation of institutional controls. The benefits of the current operations should not be significantly increased.

The reliability of the French Drain and Building 891 water treatment system is well documented in the IM/IRA reports. The planned addition of a GAC unit to the Building 891 water treatment system to remove CCl_4 does not present any significant difficulties since the GAC unit exists onsite and is readily available. Groundwater monitoring will continue until the groundwater consistently remains below the PRGs and the agencies agree that the site is no longer a cause for concern. For the purposes of the detailed analysis, a 30 year period of monitoring is assumed for the site.

Implementability of this alternative is not limited by the availability of services and materials associated with this alternative. Institutional controls proposed under this alternative, such as deed or well restrictions, could be implemented with no significant administrative problems.

4.3.2.7 Cost

Capital costs associated with Alternative 1 include the installation of four groundwater monitoring wells. The O&M costs include operation of the Building 891 water treatment system for 30 years, and the post-closure costs consist groundwater monitoring for 30 years. Total

capital cost for this alternative is \$63,800, the total O&M cost is \$5,761,200, and the total post closure cost is \$1,740,400. The total cost of this alternative is \$7,565,400. A detailed cost estimate for this alternative is included in Appendix A.

4.3.3 Alternative 2. Groundwater Pumping and Soil Vapor Extraction

The evaluation of the two threshold and five balancing criteria for Alternative 2 Groundwater Pumping and Soil Vapor Extraction is summarized in the following subsections.

4.3.3.1 Overall Protection of Human Health and the Environment

Alternative 2 should be protective of human health and the environment because it extracts and remediates contaminated groundwater and soil vapor. The exposure potential at the site is reduced by remediating the primary contaminant source and reducing contaminant concentrations to the PRGs. SVE and groundwater extraction will decrease contaminant mobility and volume. The French Drain will capture contaminated groundwater and prevent downgradient migration of contaminants for 10 years after remediation is completed.

The RCRA CAP criteria for controlling contamination sources should be satisfied by the components of this alternative. It should also meet the RCRA CAP criteria for attaining cleanup standards for all of the contaminants except possibly TCE. Groundwater modeling indicates that the contaminant concentrations, except perhaps TCE, should be below the PRGs at the downgradient side of the French Drain and the alluvium of Woman Creek.

Woman Creek is an intermittent stream which requires protection for ecological receptors under various regulatory programs. Chemical specific ARARs for OU 1 should be met by groundwater extraction and SVE based on results of groundwater monitoring. Woman Creek surface water standards should be met for human and ecological receptors.

Alternative 2 is easily implemented because of the availability and mobility of SVE systems.

The degree of permanence depends on the degree to which the primary contaminant source is remediated by the SVE system. Fractured bedrock and low aquifer transmissivity may not be amenable to rapid and complete remediation of DNAPL sources. In addition, the locations of DNAPL sources are not well known. For SVE and groundwater extraction to completely remediate DNAPL, the well should be located within or near the DNAPL source. Otherwise, the extraction rate depends on the passive partitioning capability of the compound to groundwater.

This alternative would remediate the primary contaminant source at IHSS 119.1. Carcinogenic risks at the French Drain and Woman Creek are currently below the acceptable risk range of 10^{-4} to 10^{-6} ; therefore, implementation of this alternative should lower the risk range well below 1 in 1,000,000. Noncarcinogenic hazard indices for the French Drain and Woman Creek do not indicate a potential for adverse effects to human health.

The implementation phase of Alternative 2 should be completed in 4 years, depending on the soil properties, contaminant concentrations, carbon type, and volumes of contaminated subsurface soil and groundwater. During implementation, there should be no additional short-term risks to the public. Potential risks to on-site workers include exposure to contaminants in contaminated groundwater and soil vapor and safety hazards associated with drilling and construction activities. Risks will be minimized through standard health and safety practices.

4.3.3.2 Compliance With Applicable or Relevant and Appropriate Requirements

Three types of ARARs: chemical specific, action specific, and location specific, are evaluated for each alternative. The following sections evaluate the key ARARs specific to this alternative.

Chemical Specific ARARs

The results of groundwater monitoring from 1989-1994 indicate that the State Basic Standards for Groundwater (5 CCR 1002.8.3.11.5) are currently exceeded beneath OU 1. Specific

chemical concentrations which exceed standards are PCE 1 2 DCA 1 1 DCE 1 2 DCE(cis)
CCl₄ 1 1 1 TCA and TCE

Organic chemical concentrations have been modeled to reflect remediation activities at OU 1 using groundwater monitoring results and the knowledge of hydrogeological conditions. The results of groundwater modeling of the chemicals indicate that Alternative 2 would comply with Basic Standards for Groundwater 10 years after implementation of remediation assuming the French Drain is in place. The French Drain location would achieve the State Basic Standards after the 10th year with the exception of TCE according to the modeling results. However the steady state model assumes the source of contamination remains during the period of remediation. Contaminants at the location of Woman Creek would comply with the State Groundwater Standards sooner than 10 years after remediation. Assumptions of the model and results of the model are discussed in Appendix B.

Action Specific ARARs

Some contaminants would be left in place at the IHSSs (other than 119 1) within OU 1. The sources at IHSS 119 would be remediated to reduce contaminant concentrations. Collection of the mobile contaminants in groundwater at the French Drain and subsequent treatment of contaminants in the water treatment system would continue for as long as is necessary to achieve the State groundwater standards. There is a potential for some contaminants to be left in place at some of the IHSSs since groundwater movement is sporadic and subject to climatic conditions.

Compliance with 6 CCR 1007.3-264.90 and 264.101 of the State RCRA program is required at OU 1. Compliance with either the RCRA definition of point of compliance or the State groundwater regulatory definition will depend upon the selection of a point of compliance location by EPA, CDPHE and DOE.

A plan to monitor contaminants would be required for the post closure period. A RCRA

performance monitoring system would be implemented with this alternative and would probably be needed for 10 years after remediation according to a review of modeling results. Monitoring of the organic and inorganic constituents would be conducted in accordance with Subpart F of the State RCRA regulations (6 CCR 1007.3.264.93.264.98). Monitoring would be conducted until it is determined that the contaminants are in compliance with the State Basic Standards for Groundwater (5 CCR 1002.8.3.11.5). The state groundwater standards are selected for monitoring since the RCRA regulations do not have protection standards for the contaminants except for selenium.

Corrective action would be conducted as long as necessary to achieve the state groundwater standards at the selected point of compliance. Maintenance and monitoring of constituents is required to be conducted for 30 years unless the performance monitoring system indicates no exceedances of groundwater standards for three consecutive years and a shortened period of time is approved by CDPHE. According to the results of the modeling, the time period for requiring monitoring could be 10 years after source remediation; however, an initial post closure period of 30 years would be initiated with CDPHE. Implementation of this alternative would require a determination by CDPHE that the corrective action is protective of human health and the environment. The point of compliance for the performance monitoring system would need to be selected to demonstrate compliance with the RCRA corrective action requirements and the groundwater protection standard (Subpart F).

Other action specific ARARS such as the Colorado Water Quality Control Act effluent limitations for the water treatment system would be complied with during operation of the system.

The SVE system may be considered to be a temporary RCRA unit because it treats hazardous waste constituents. Therefore, the requirements of Subpart S (6 CCR 1007.3 Subsection 264.553) are applicable. In addition, any pre filters, HEPA filters, and GAC used to remove VOCs in the off gas treatment system should comply with the following provisions:

- Identification of hazardous waste (Part 261)
- Air emission standards for process vents (Subsection 264 1033)
- Air emission standards for equipment leaks (Subsections 264 1052 264 1054 and 264 1057)
- Land disposal restrictions (Part 268)

It is anticipated that the operation and mobilization/demobilization of the SVE treatment unit and treatment residuals should comply with the applicable requirements of RCRA and CHWA

The Colorado Solid Waste Regulations (6 CCR 1007 2) are an ARAR for disposal of any residual materials that are not hazardous waste. If solid waste disposal is necessary, it should be in accordance with the regulations.

Installation of additional extraction and monitoring wells should be in accordance with the Colorado Water Well and Pump Installation Regulations (2 CCR 402 2)

Location Specific ARARs

Alternative 2 should comply with laws and regulations regarding wetlands and threatened and endangered or special concern species. There may be a short term impact to wetlands from decommissioning the French Drain but the anticipated long term effect is an increase in wetland areas. Mitigation measures will be used to minimize effects of the alternative on wetland habitat in and near OU 1. The CDOW will be consulted prior to disturbing wetland habitat to implement adequate mitigation measures for protection of Preble's meadow jumping mouse.

4 3 3 3 Long Term Effectiveness and Permanence

The primary contaminant source at IHSS 119 1 should be remediated under Alternative 2. The French Drain will continue to capture any contaminated groundwater still migrating from IHSS 119 1 after the SVE unit is removed. Groundwater modeling indicates that the groundwater

should achieve the State groundwater standards after 10 years. However, the French Drain would operate until the groundwater meets PRGs. Natural degradation, in addition to the SVE unit, will be a factor in ensuring long term effectiveness. A 5 year review of the site is required to determine if the most effective remedy is still being used at OU 1.

In general, SVE and groundwater extraction are proven technologies for remediating contaminated sites. However, the degree of permanence after remediation will depend on the extent of DNAPL contamination outside of IHSS 119.1. The geology of OU 1 may not be amenable to rapid and complete remediation of DNAPL contamination. The soil has a low permeability and may develop preferential vapor channeling or short circuiting. A cap, such as a geotextile fabric, will be placed around each SVE well to minimize the tendency for short circuiting. The location of DNAPL at the site is still uncertain and, to ensure complete remediation, the SVE and groundwater wells should be located within or near the source. Otherwise, the extraction rate will strictly depend on the contaminant's partition coefficient.

Alternative 2 should provide long term protection for potential human receptors by minimizing the human health risk associated with contaminated groundwater. The calculated carcinogenic risks for the French Drain and Woman Creek are below the acceptable risk range of 10^{-4} to 10^{-6} . Noncarcinogenic hazard indices for the French Drain and Woman Creek do not indicate a potential for adverse effects to human health.

4.3.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 2 satisfies the NCP preference for treatment as a principal element of an alternative. Groundwater extraction and SVE should reduce the volume and mobility of contaminants in groundwater and the unsaturated zone, respectively. Groundwater extraction and SVE will reduce the volume by physically removing the contaminants. Removing the contaminants will also reduce their mobility by preventing potential migration.

Extracted groundwater will be treated in the Building 891 water treatment system using UV/

H₂O₂ and ion exchange processes UV/H₂O₂ is a destructive treatment process and will decrease the contaminant toxicity During ion-exchange resin regeneration, the toxicity will be decreased because the regenerant will be treated to destroy the contaminants contaminant toxicity will also be reduced as the GAC from the SVE process is regenerated offsite

Wastes generated as a result of this alternative will be managed according to applicable regulations Types of wastes include spent GAC from the off gas treatment system and Building 891 water treatment system liquid from the SVE vapor/liquid separator regenerant solution from ion exchange resins in the Building 891 water treatment system and wastes associated with well installation such as drill cuttings and decontamination water The spent GAC will be shipped offsite for regeneration and regenerant solution will be sent to Building 374 for evaporation The decontamination water and liquid from the SVE liquid/vapor separator will be sent through the Building 891 water treatment system There are no significant human health or environmental risks associated with handling the ion exchange resins and shipping the spent GAC

4 3 3 5 Short Term Effectiveness

Short term effectiveness will be achieved through the SVE and groundwater extraction system operations Potential short term impacts on the environment include minor disturbances to subsurface soil and displacement or loss of vegetation during well installation activities The decommission of the French Drain may temporarily decrease wetland acreage but it is expected that the long term effect will be an increase in the number of wetland acres

Short term risks to the public are minimal for Alternative 2 Risks to workers during remediation include potential exposures to contaminants in extracted groundwater or soil vapor and safety hazards associated with drilling and other construction activities Risks to workers will be minimized through standard construction health and safety procedures

4 3 3 6 Implementability

Alternative 2 is easily implemented because SVE and groundwater extraction are commonly used technologies that do not require unique or unusual equipment. The implementability of this alternative should not be limited by the availability of services and materials nor should there be significant administrative difficulties. The combination of low contaminant concentrations and soil permeability may make it more difficult to implement the alternative. An SVE treatability study at OU 2 has been discontinued with a recommendation to not use SVE at the site.

The ability to perform future remedial actions, if any, should not be limited by using SVE and groundwater extraction. A performance monitoring program will monitor the concentration of contaminants for 13 years or more after completion of SVE. Vapor and radiological monitoring programs will be implemented during construction and remediation.

Vapor extraction wells can be installed using standard drilling techniques and construction materials. Operation of the SVE system should not require highly specialized personnel or training. A vapor monitoring program will be conducted at portals near the wells and the GAC units to determine the SVE system's efficiency and approximate replacement rates for the GAC.

4 3 3 7 Cost

Costs for Alternative 2 include costs of the following items:

- Soil gas survey (approximately 100 probes)
- Three groundwater extraction wells (6 inch diameter 20 foot depth)
- 36 vapor extraction wells (4 inch diameter 20 foot depth)
- Three vapor extraction systems with blowers and filters
- Activated carbon adsorption system (2 vessels containing 1 500 pounds each)
- Associated piping, pumps, and instrumentation
- Four groundwater monitoring wells (6-inch diameter 20 foot depth)
- Operation of the building 891 water treatment system
- Groundwater monitoring

The total capital cost for Alternative 2 is \$925 600 The total O&M cost is \$5 287 700 assuming operation of the Building 891 treatment system during the four year SVE treatment period and 10 years following completion of SVE The total post closure cost of this alternative is \$833 300 including groundwater monitoring for 13 years following completion of remediation The total cost of this alternative is \$7 046 600 A detailed cost estimate is included in Appendix A

4 3 4 Alternative 3 Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement

The evaluation of the two threshold and five balancing criteria for Alternative 3 Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement is summarized in the following sections

4 3 4 1 Overall Protection of Human Health and the Environment

Alternative 3 protects human health and the environment by removing DNAPLs from groundwater and remediating the subsurface soil in situ The potential for exposure is reduced by remediating the primary contaminant source and reducing contaminant concentrations in groundwater to the PRGs SVE and groundwater extraction will reduce contaminant mobility and volume

The RCRA CAP criteria for controlling contamination sources will be satisfied by the components of this alternative It will also meet the RCRA CAP criteria for attaining cleanup standards for all of the contaminants except possibly TCE Groundwater modeling indicates that the peak contaminant concentrations except perhaps TCE would achieve PRGs at Woman Creek Peak PCE TCE and CCl_4 concentrations are above the PRGs at the French Drain but the groundwater model does not account for the operation of the French Drain after the alternative is implemented The French Drain should still be collecting groundwater at the time of the peak concentrations

Chemical specific ARARs should be met by using SVE and groundwater extraction 10 years after implementation of these technologies. Woman Creek is an intermittent stream which is a concern to the ecological receptors. Surface water standards established for ecological receptors should be met at Woman Creek.

Protection of human health and the environment will be achieved by removal of the source to the extent practicable. The removal after remediation will depend on the location of the source of contamination. For SVE and groundwater extraction to completely remediate DNAPL sources, the wells must be located near or in the DNAPL source. Otherwise, the extraction rate depends on the passive partitioning capability of the compound. The geology of OU 1 may also not be amenable to rapid and complete remediation of DNAPL contamination. Factors that can be controlled such as groundwater and vapor extraction rates will be optimized to increase the degree of remediation possible at the site.

Groundwater should be protected downgradient of and within the OU 1 boundaries. The French Drain will capture groundwater for at least 10 years following completion of remediation before being decommissioned. Because models are based on assumptions about a site, groundwater monitoring will be performed for an additional 3 years to ensure that contaminant concentrations remain consistently below the PRGs.

RF heating may have an adverse effect on the subsurface soil due to the high temperatures required by the in situ process. While the elevated temperatures will increase the removal efficiency of the contaminants, some subsurface and surface biota may not be able to withstand the sustained high temperatures. It is expected that the majority of biota will be able to repopulate itself within a reasonable amount of time.

Alternative 3 can perhaps be implemented with few administrative difficulties because SVE and groundwater extraction are well known processes with documented performances. However, an SVE treatability study at OU 2 has been discontinued because of low contaminant concentrations at the site. RF heating is an innovative technology which could cause some

dislocation of fauna and destruction of flora The areas currently targeted for this technology are a distance from the riparian habitat of Preble's meadow jumping mouse

Because Alternative 3 should remediate the primary contaminant source at IHSS 119.1, modeling shows that the carcinogenic risks at the French Drain and Woman Creek should be below the acceptable risk range of 10^{-4} to 10^{-6} . The noncarcinogenic hazards associated with this alternative at the French Drain and Woman Creek do not indicate a potential for adverse effects to human health.

The implementation of SVE with thermal enhancement should be completed within 3 years. During implementation, there are no unacceptable short-term risks to the public, although there may be some risks to flora and fauna at the site. There may also be potential risks to on-site workers from exposure to contaminated water or soil vapor, in addition to safety hazards associated with drilling, construction activities, and operating the RF heating elements. Risks will be minimized through standard health and safety practices.

4.3.4.2 Compliance With Applicable or Relevant and Appropriate Requirements

Three types of ARARs: chemical specific, action specific, and location specific, are evaluated for each alternative. The following sections evaluate the key ARARs specific to this alternative.

Chemical Specific ARARs

The results of groundwater monitoring from 1989-1994 indicate that the State Basic Standards for Groundwater (5 CCR 1002.8.3-11.5) are currently exceeded beneath OU 1. Specific chemical concentrations which exceed standards are PCE, 1,2-DCA, 1,1-DCE, 1,2-DCE(cis), CCl_4 , 1,1,1-TCA, and TCE.

Organic chemical concentrations have been modeled to reflect remediation activities at OU 1 using groundwater monitoring results and the knowledge of hydrogeological conditions. The

results of groundwater modeling of the chemicals indicate that Alternative 3 would comply with Basic Standards for Groundwater 10 years after implementation of remediation assuming the French Drain is in place. The French Drain location would achieve the State Basic Standards after the 10th year with the exception of TCE according to the modeling results. However the steady state model assumes the source of contamination remains during the period of remediation. Contaminants at the location of Woman Creek would comply with the State Groundwater Standards sooner than 10 years after remediation. Assumptions of the model and results of the model are discussed in Appendix B.

Action Specific ARARs

The action specific ARARs associated with Alternative 3 are the same as presented in Alternative 2. Compliance with RCRA requirements for identification, storage, and disposal of hazardous waste and organic air emissions and leaks should be achieved. Compliance with other action specific ARARs is anticipated to be similar to the compliance discussed under Alternative 2.

Some contaminants would be left in place at the IHSSs (other than 119.1) within OU 1. The sources at IHSS 119 would be remediated to reduce contaminant concentrations. Collection of the mobile contaminants in groundwater at the French Drain and subsequent treatment of contaminants in the water treatment system would continue for as long as is necessary to achieve the State groundwater standards. There is a potential for some contaminants to be left in place at some of the IHSSs since groundwater movement is sporadic and subject to climatic conditions.

Compliance with 6 CCR 1007.3, 264.90 and 264.101 of the State RCRA program is required at OU 1. Compliance with either the RCRA definition of point of compliance or the State groundwater regulatory definition will depend upon the selection of a point of compliance location by EPA, CDPHE, and DOE.

A plan to monitor contaminants would be required for the post closure period. A RCRA

performance monitoring system would be implemented with this alternative and would probably be needed for 10 years after remediation based on modeling results. Monitoring of the organic constituents would be conducted in accordance with Subpart F of the State RCRA regulations (6 CCR 1007.3.264-93.264-98). Monitoring would be conducted until it is determined that the contaminants are in compliance with the State Basic Standards for Groundwater (5 CCR 1002.8.3.11.5). The state groundwater standards are selected for monitoring since the RCRA regulations do not have protection standards for the contaminants except for selenium.

Corrective action would be conducted as long as necessary to achieve the state groundwater standards at the selected point of compliance. Maintenance and monitoring of constituents is required to be conducted for 30 years unless the performance monitoring system indicates no exceedances of groundwater standards for three consecutive years and a shortened period of time is approved by CDPHE. According to the results of the modeling, the time period for requiring monitoring could be 10 years after source remediation; however, an initial post-closure period of 30 years would be initiated with CDPHE. Implementation of this alternative would require a determination by CDPHE that the corrective action is protective of human health and the environment. The point of compliance for the performance monitoring system would need to be selected to demonstrate compliance with the RCRA corrective action requirements and the groundwater protection standard (Subpart F).

Other action specific ARARS, such as the Colorado Water Quality Control Act effluent limitations for the water treatment system, would be complied with during operation of the system.

Location Specific ARARs

Assuming additional extraction wells are placed away from the French Drain and Pond C 1, destruction of riparian vegetation and fauna during thermal enhancement should be minimal. Compliance with DOE wetland protection regulations and the State's law concerning non game species should be achieved if this alternative is implemented. Should it be necessary, riparian

habitat will be replaced if it is destroyed by RF heating

Impacts from decommissioning the French Drain may result in a short term loss of wetlands. However, it is anticipated that the net effect of the decommissioning should be a long term gain in wetland acreage.

4.3.4.3 Long Term Effectiveness and Permanence

Alternative 3 should remediate the primary contaminant source at IHSS 119.1. The French Drain and extraction wells will extract contaminated groundwater for 10 years after implementation of the SVE and RF heating. Because models are based on assumptions about a site, an additional 3 years of groundwater monitoring will be used to ensure long term effectiveness. It is assumed that the low initial contaminant concentrations will be a factor in ensuring long term effectiveness. A 5 year review of the site will be conducted to determine the effectiveness of the alternative.

Alternative 3 may provide a high degree of permanence because thermal enhanced SVE should remove more residual contaminants trapped within the subsurface soil at OU 1 than normal SVE operation. However, the degree of permanence after remediation will depend on the exact location of the source of contaminants. The locations of DNAPL are not well-defined and for SVE and groundwater extraction to completely remediate a site, the wells must be located near or in the DNAPL. Otherwise, the process depends on the passive partitioning capability of the contaminant. In addition, the geology of OU 1 may not be amenable to rapid and complete remediation of DNAPL contamination. The soil has a low permeability and may develop preferential vapor channeling or short circuiting. To minimize the tendency for short circuiting, a cap such as a geotextile fabric will be placed around each SVE well.

Long term protection for human and ecological receptors should begin shortly after the alternative is implemented. The calculated carcinogenic risks at the French Drain and Woman Creek after implementation of this alternative are below the acceptable risk range of 10^{-4} to 10^{-6} .

° The noncarcinogenic hazards associated with this alternative at the French Drain and Woman Creek do not indicate a potential for adverse effects to human health. A 5 year review will be conducted to determine the continued effectiveness of this alternative.

Wastes generated as a result of this alternative will be managed in compliance with applicable regulations. The wastes include liquid from the SVE liquid/vapor separator, spent GAC from the off gas treatment system and Building 891 water treatment system, regenerants solution from ion exchange resins in the Building 891 water treatment system, and wastes associated with well installations such as drill cuttings and decontamination water. The SVE liquid/vapor separator waste and the decontamination water can be sent to Building 891. The regenerant solution from the ion exchange resins will be pH neutralized and sent to Building 374 for evaporation. The spent GAC will be sent offsite for regeneration. There are no significant risks associated with handling the resins or shipping the spent GAC.

4.3.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 3 satisfies the NCP preference for treatment as a principal element of the alternative. The volume and mobility of the DNAPLs are reduced through groundwater extraction and thermally enhanced SVE. Physically removing the contaminants will reduce their mobility by preventing additional migration.

Extracted groundwater and waste from the SVE liquid/vapor separator will be treated at Building 891 by UV/Peroxide and ion-exchange processes. UV/H₂O₂ is a destructive water treatment process and results in decreased toxicity. Spent GAC from the SVE off gas treatment system will be regenerated offsite resulting in an additional reduction in toxicity.

Contaminated materials generated as a result of this alternative include GAC from the off gas treatment system and Building 891 water treatment system, liquid from the SVE liquid/vapor separator, regenerants solution from ion-exchange resins in the Building 891 water treatment system, and wastes associated with well installation such as drill cuttings and decontamination

water The regenerants solution from ion exchange resins will be pH neutralized and sent to Building 374 for evaporation The liquid from the SVE separator and decontamination water will be sent to Building 891 for treatment The spent GAC will be shipped offsite for treatment There are no significant risks associated with handling the regenerant solution or shipping the spent GAC

4 3 4 5 Short Term Effectiveness

Protection of human health and the environment should begin shortly after implementing Alternative 3 Potential short term impacts on the environment include disturbance to the subsurface soil and displacement or loss of vegetation during construction activities The RF heating may adversely affect some subsurface biota due to high soil temperatures but it is anticipated that the biota will repopulate within a reasonable amount of time Decommissioning the French Drain may result in a short term loss of wetlands but it is anticipated that the net effect of the decommission should be a gain in wetland acreage

Potential short term impacts to the public are minimal under Alternative 3 Potential risks to workers during remediation activities include exposure to contaminants in extracted groundwater or soil vapor There may be safety hazards associated with drilling and other construction activities as well as with the operation of the RF heating devices Risks to workers will be minimized through standard health and safety practices

4 3 4 6 Implementability

Alternative 3 can be readily implemented SVE and groundwater extraction are proven and commonly used technologies that do not require unique or unusual equipment Although RF heating is a less common variation of the SVE process it is available through specialized vendors The implementability of Alternative 3 should not be limited by the availability of services and materials nor should there be significant administrative difficulties Because of the low soil permeability and contaminant concentrations there may be technical difficulties in

implementing a SVE system A treatability study at OU 2 indicated that SVE was not a good option for that site

The ability to conduct future remedial actions if necessary should not be limited by implementation of thermally enhanced SVE and groundwater extraction Groundwater monitoring will track potential movement of contaminants for at least 13 years Vapor and radiological monitoring will be conducted during the construction and remediation

Vapor extraction wells will be installed using standard drilling techniques and construction materials Operation of the basic SVE system should not require highly specialized personnel or training however operation of the RF heating antennae may require special training or assistance from the vendor The RF antennae can be installed in one or more of the vapor extraction wells and moved from one well to another as required by the treatment process RF heating does not produce treatment residual waste

A vapor monitoring program conducted at the wells and GAC units, will monitor the SVE system s efficiency and determine replacement rates for the GAC units Spent GAC from the off gas treatment system and the Building 891 water treatment system will be sent offsite for regeneration Ion exchange resins from the Building 891 water treatment system will be regenerated onsite and the regenerants solution pH neutralized and sent to Building 374 for evaporation Liquid from the SVE liquid/vapor separator and decontamination water will be sent to the Building 891 water treatment system

4 3 4 7 Cost

Costs for Alternative 3 include the following items

- Soil gas survey (approximately 100 probes)
- Three groundwater extraction wells (6-inch diameter, 20 foot depth)
- 36 vapor extraction wells (4-inch diameter 20-foot depth)
- Four groundwater monitoring wells (6 inch diameter 20 foot depth)
- Three vapor extraction systems with blowers filters and other appurtenances

- GAC system (two skid mounted units containing 1 500 pounds of GAC each)
- RF heating unit
- Associated piping pumps and instrumentation
- Operation of the building 891 water treatment system
- Groundwater monitoring

The total capital cost of Alternative 3 is \$1 843 600 The total O&M cost is \$4 798 200 assuming operation of the building 891 treatment system during the two year SVE treatment period and for 10 years following SVE The total post closure cost for this alternative is \$918 700 including groundwater monitoring for 13 years following completion of remediation The total cost of this alternative is \$7 560 500 A detailed cost estimate is included in Appendix A

4 3 5 Alternative 4. Hot Air Injection with Mechanical Mixing

The evaluation of the two threshold and five balancing criteria for Alternative 4 Hot Air Injection with Mechanical Mixing is summarized in the following subsections

4 3 5 1 Overall Protection of Human Health and the Environment

Alternative 4 protects human health and the environment by removing DNAPL contaminants from subsurface soil and if possible groundwater at IHSS 119 1 The exposure potential is reduced by decreasing the volume of contaminants through groundwater extraction and remediation of the primary contaminant source The French Drain and extraction wells will decrease contaminant mobility by capturing contaminated groundwater and preventing downgradient migration of contaminants

The RCRA CAP criteria for controlling contamination sources will be satisfied by the components of this alternative It will also meet the RCRA CAP criteria for attaining cleanup standards for all of the contaminants except possibly TCE Groundwater modeling indicates that the peak contaminant concentrations at Woman Creek except perhaps TCE will be below the PRGs According to the model TCE PCE and CCl₄ may not meet the PRGs at the French

Drain however the model does not include the French Drain which should be operating to reduce peak concentrations

Alternative 4 should meet key ARARs at the French Drain and Woman Creek The intermittent stream status of Woman Creek is a concern to ecological receptors Surface water standards established for ecological receptors should be met at Woman Creek

Hot air injection may have an adverse effect on the soil at OU 1 due to the high soil temperatures that are reached during operation While the elevated temperatures may increase the effectiveness of the alternative they may be harmful to some subsurface biota in the short term It is expected that the biota will repopulate itself in a reasonable amount of time

Alternative 4 should provide permanence by remediating the primary contaminant area at IHSS 119 1 and reducing long term risks to human health and the environment The degree of permanence achieved at the site depends on the extent that the primary contaminant area is remediated Uncertainties regarding the nature and extent of the DNAPL sources may limit the degree of permanence achieved by Alternative 4

Because this alternative should remediate the source at IHSS 119 1, groundwater modeling indicates that carcinogenic risk levels at the French Drain and Woman Creek are below the acceptable risk range of 10^{-4} to 10^{-6} Noncarcinogenic hazard indices for the French Drain and Woman Creek do not indicate a potential for adverse effects to human health

This alternative should be completed in approximately 1 year depending on the actual volumes of contaminated soil and groundwater contaminant concentrations and mobilization time There should be no additional short term risks to the public during implementation Potential health risks to on site workers occur from exposure to contaminants in groundwater and soil vapor and safety hazards associated with construction activities hot air injection and operation of the mechanical mixer tool Risks will be minimized through standard health and safety practices

4 3 5 2 Compliance With Applicable or Relevant and Appropriate Requirements

Three types of ARARs chemical specific action specific and location specific are evaluated for each alternative The following sections evaluate the key ARARs specific to this alternative

The designation of ARARs for this alternative is the same as presented in Alternative 3 Alternative 4 should comply with chemical specific action specific and location specific ARARs

Chemical Specific ARARs

The results of groundwater monitoring from 1989 1994 indicate that the State Basic Standards for Groundwater (5 CCR 1002 8 3 11 5) are currently exceeded beneath OU 1 Specific chemical concentrations which exceed standards are PCE, 1 2 DCA, 1 1 DCE, 1,2 DCE(cis) CCl₄ 1 1 1 TCA and TCE

Organic chemical concentrations have been modeled to reflect remediation activities at OU 1 using groundwater monitoring results and the knowledge of hydrogeological conditions The results of groundwater modeling of the chemicals indicate that Alternative 4 would comply with Basic Standards for Groundwater 10 years after implementation of remediation, assuming the French Drain is in place The French Drain location would achieve the State Basic Standards after the 10th year with the exception of TCE according to the modeling results However the steady state model assumes the source of contamination remains during the period of remediation contaminants at the location of Woman Creek would comply with the State Groundwater Standards sooner than 10 years after remediation Assumptions of the model and results of the model are discussed in Appendix B

Action Specific ARARs

Alternative 4 similar to Alternative 3 may enhance the volume of contaminants that can be

extracted from the soil Vapor monitoring will be used to determine the effectiveness of the system and to ensure that breakthrough does not occur in the GAC systems

Some contaminants would be left in place at the IHSSs (other than 119:1) within OU 1 The sources at IHSS 119 would be remediated to reduce contaminant concentrations Collection of the mobile contaminants in groundwater at the French Drain and subsequent treatment of contaminants in the water treatment system would continue for as long as is necessary to achieve the State groundwater standards There is a potential for some contaminants to be left in place at some of the IHSSs since groundwater movement is sporadic and subject to climatic conditions

Compliance with 6 CCR 1007.3-264.90 and 264.101 of the State RCRA program is required at OU 1 Compliance with either the RCRA definition of point of compliance or the State groundwater regulatory definition will depend upon the selection of a point of compliance location by EPA CDPHE and DOE

A plan to monitor contaminants would be required for the post closure period A RCRA performance monitoring system would be implemented with this alternative and would probably be needed for 13 years or more after remediation according to the modeling results Monitoring of the organic constituents would be conducted in accordance with Subpart F of the State RCRA regulations (6 CCR 1007.3-264.93-264.98) Monitoring would be conducted until it is determined that the contaminants are in compliance with the State Basic Standards for Groundwater (5 CCR 1002.8-3-11.5) The state groundwater standards are selected for monitoring since the RCRA regulations do not have protection standards for the contaminants except for selenium

Corrective action would be conducted as long as necessary to achieve the state groundwater standards at the selected point of compliance Maintenance and monitoring of constituents is required to be conducted for 30 years unless the performance monitoring system indicates no exceedances of groundwater standards for three consecutive years and a shortened period of time is approved by CDPHE According to the results of the modeling the time period for requiring

monitoring could be as short as 13 years after source remediation however an initial post closure period of 30 years would be initiated with CDPHE Implementation of this alternative would require a determination by CDPHE that the corrective action is protective of human health and the environment The point of compliance for the performance monitoring system would need to be selected to demonstrate compliance with the RCRA corrective action requirements and the groundwater protection standard (Subpart F)

Other action specific ARARS such as the Colorado Water Quality Control Act effluent limitations for the water treatment system would be complied with during operation of the system Other action specific ARARS should be complied with in a manner similar to Alternative 3

Location Specific ARARS

It is assumed that mechanical mixing hot air injection and extraction well installation will not be completed in the riparian habitat near the French Drain and Pond C 1 Riparian habitat will be replaced if it is inadvertently destroyed by the hot air from the mechanical mixer It is anticipated that compliance with DOE and Colorado regulations concerning wetlands and nongame species should be achieved with the implementation of this alternative

4 3 5 3 Long Term Effectiveness and Permanence

Alternative 4 should protect human health and the environment by removing contaminated groundwater and remediating contaminated soil at IHSS 119 1 The French Drain will extract and treat contaminated groundwater at IHSS 119 1 until the groundwater is reduced below the PRGs Groundwater modeling indicates that the groundwater should be free from DNAPL contamination within 10 years Because groundwater models are based on assumptions about a site however three additional years of monitoring and operation of the French Drain will be conducted to ensure that the groundwater remains below the PRGs The additional monitoring and collection should provide long term effectiveness and minimize the risk to human health and

the environment The low contaminant concentrations and natural degradation should also be a factor in providing long term effectiveness

The carcinogenic risks from IHSS 119 1 at the French Drain and Woman Creek are below the acceptable risk range of 10^{-4} to 10^{-6} primarily because the DNAPL contamination is remediated at IHSS 119 1 Noncarcinogenic hazard indices at the French Drain and Woman Creek do not indicate a potential for adverse effects to human health

The mechanical mixer hot air injection process should provide a large degree of permanence if the primary contaminant source is fully remediated The process maximizes the chance for full remediation by providing a homogenous mixture high airflow through the soil and an increased soil permeability for ease of removing contaminants Uncertainties regarding the nature and extent of the DNAPL contamination may limit the permanence of this alternative A 5 year review of the alternative will be used to determine the degree of remediation achieved by the mechanical mixer hot air injection process

Wastes generated as a result of this alternative will be managed in compliance with applicable regulations The wastes include liquid from a SVE liquid/vapor separator spent GAC from the off gas treatment system and Building 891 water treatment system regenerant solution from ion exchange resins in the Building 891 water treatment system and wastes associated with well installation such as drill cuttings and decontamination water The liquid/vapor separator waste and the decontamination water can be sent to Building 891 The regenerant solution from the ion-exchange resins will be pH neutralized and sent to Building 374 for evaporation The spent GAC will be sent offsite for regeneration There are no significant risks associated with handling the regenerant solution and shipping the spent GAC

4 3 5 4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 4 should satisfy the NCP preference for treatment as a principal element of an alternative Removing DNAPLs from the subsurface soil and groundwater will effectively

reduce the mobility and volume of contaminants at IHSS 119 1 The mechanical mixer hot air injection process should increase the soil permeability and volatilization rate thereby increasing the volume of contaminants that can be removed from the subsurface soil Groundwater extraction will reduce the contaminant volume in groundwater and the French Drain will prevent potential migration of the contaminants outside of OU 1 Remediating the subsurface soil and groundwater will reduce contaminant mobility by preventing potential downgradient migration

Extracted groundwater and waste from the liquid/vapor separator will be treated by UV/H₂O₂ ion exchange and GAC processes in the Building 891 water treatment system UV/H₂O₂ is a destructive treatment process and will result in decreased contaminant toxicity GAC from the off gas treatment system will be regenerated offsite resulting in reduced contaminant toxicity

Wastes generated as a result of this alternative will be managed in compliance with applicable regulations The wastes include liquid from a liquid/vapor separator spent GAC from the off gas treatment system and Building 891 water treatment system regenerant solution from ion exchange resins in the Building 891 water treatment system and wastes associated with well installation such as drill cuttings and decontamination water

4 3 5 5 Short Term Effectiveness

Protection of human health and the environment should begin shortly after implementing Alternative 4 Short term impacts on the environment include soil disturbance and displacement or loss of vegetation during remedial activities The hot air injection and mechanical mixing may affect some subsurface biota due to the high temperatures that are reached during operation but it is expected that the biota will repopulate itself within a reasonable amount of time

Groundwater modeling for Alternative 4 indicates that the peak concentrations at Woman Creek are below the surface water standards The actual peak concentrations should be less than the modeled concentrations because the model assumed that the French Drain would be decommissioned when the alternative was implemented Ecological receptors may be more

affected by Woman Creek's intermittent stream status than by the contaminant concentrations

Potential short term impacts to the public are minimal under this alternative. Potential risks to workers during remediation include exposure to contaminants in extracted groundwater and soil vapor. Workers may also be exposed to health and safety hazards associated with the operation of the mechanical mixer. Mixing the soil may increase the risks associated with operating heavy equipment because of the increased possibility of unstable soil. The risks will be minimized through standard health and safety practices.

4.3.5.6 Implementability

Although the technology is not as common as other applicable technologies, equipment for hot air injection and mechanical mixing is available from specialized vendors. Alternative 4 should not have any significant administrative difficulties unless the hot air injection and mechanical mixing are conducted in the riparian habitat areas along Woman Creek.

The technology may be difficult to implement due to the instability of the claystone soil found at OU 1. Safety hazards may occur during remediation because the mixing may increase the possibility for slope failures by decreasing the soil's cohesive properties. Also, the treatment zone may become completely mixed, saturated, and soft as the remediation progresses. Installing the necessary dewatering and monitoring wells into the treatment zone may be difficult if a drill rig cannot be driven onto the soil.

4.3.5.7 Cost

Costs for Alternative 4 include the following items:

- Soil gas survey (approximately 100 probes)
- Four groundwater monitoring wells
- Mechanical mixing unit (including off gas treatment)
- Associated piping, pumps, and instrumentation
- Operation of the building 891 water treatment system

- Groundwater monitoring

The total capital cost for Alternative 4 is \$1 781 400 The total O&M cost is \$3 113 000 including operation of the Building 891 treatment system for 10 years following the completion of remediation The total post closure cost is \$1 120 700 including groundwater monitoring for 13 years following completion of remediation The total cost of this alternative is \$6 015 100 A detailed cost estimate is included in Appendix A

4 3 6 Alternative 5. Soil Excavation with Groundwater Pumping

The evaluation of the two threshold and five balancing criteria for Alternative 5 Soil Excavation with Groundwater Pumping is summarized in the following subsections

4 3 6 1 Overall Protection of Human Health and the Environment

Alternative 5 will be protective of human health and the environment by using a combination of soil excavation groundwater extraction and treatment of contaminated soil and groundwater The exposure potential is reduced at the site by decreasing the contaminant concentrations through groundwater extraction and removal of the primary contaminant source The French Drain will capture contaminated groundwater and prevent downgradient migration of contaminants

The RCRA CAP standard for controlling contamination sources will be satisfied by the components of Alternative 5 Alternative 5 will also meet the RCRA CAP standard for attaining cleanup standards for all of the contaminants with the possible exception of TCE Groundwater modeling indicates that the peak contaminant concentrations except perhaps TCE will be below the PRGs at Woman Creek PCE TCE, and CCl₄ may not meet the PRGs at the French Drain but the groundwater model assumed that the French Drain operation would be discontinued when Alternative 5 is implemented

The soil excavation and groundwater extraction of Alternative 5 should allow OU 1 to meet chemical specific ARARs at the French Drain and Woman Creek. Woman Creek as an intermittent stream is a concern for ecological receptors. Surface water standards should also be met at Woman Creek for both human and ecological receptors. Alternative 5 will provide long term effectiveness because it removes the source of contamination, offers a high degree of permanence and should be an effective method for removing DNAPLs from the site. The degree of permanence is dependent on the extent to which the sources in IHSS 119 1 are remediated. Uncertainties regarding the actual nature and extent of the DNAPL sources may limit the degree of permanence achieved by Alternative 5.

Alternative 5 may have a significant impact on the environment due to the large excavation, soil storage and transportation requirements. Excavating the source area will adversely impact the flora, fauna and subsurface biota of the area. It is anticipated that proper mitigation and reclamation measures will minimize long term effects from this alternative. However, if the Preble's meadow jumping mouse becomes a Federally protected Endangered/Threatened species, the consultation process with U.S. Fish and Wildlife may require additional unanticipated measures.

The carcinogenic risk levels associated with DNAPLs at the French Drain and Woman Creek under this alternative are lower than the acceptable risk range of 10^{-4} to 10^{-6} because the primary source of contamination is removed through excavation and the contaminant groundwater plume is captured by the French Drain. The noncarcinogenic hazards associated with the alternative at the French Drain and Woman Creek do not indicate a potential for adverse effects to human health.

It is anticipated that treatment of contaminated soils should be completed within 1 to 2 years of implementation depending on the contaminant concentrations, subsurface soil volume and the capacity of the thermal desorption unit. During implementation, there is a potential for risk to the public due to contaminated fugitive dust generated during the excavation, transportation and storage of large volumes of subsurface soil. Risks to the public should be minimized by using

dust suppressants i.e. water to suppress the fugitive dust during transport and the construction of a roof or other cover for the storage areas. Potential risks to workers may occur from exposure to contaminants in groundwater, soil, and fugitive dust. Workers may encounter safety hazards associated with operating excavation/backfill equipment and the thermal desorption unit. Risks to workers will be minimized through standard health and safety practices.

4.3.6.2 Compliance With Applicable or Relevant and Appropriate Requirements

Three types of ARARs: chemical specific, action specific, and location specific, are evaluated for each alternative. The following sections evaluate the key ARARs specific to this alternative.

The ARARs associated with this alternative are very similar to those presented and discussed for Alternatives 3 and 4. Alternative 5 should comply with chemical specific, location specific, and action specific ARARs.

Chemical Specific ARARs

The results of groundwater monitoring from 1989-1994 indicate that the State Basic Standards for Groundwater (5 CCR 1002.8.3.11.5) are currently exceeded beneath OU 1. Specific chemical concentrations which exceed standards are PCE 1.2, DCA 1.1, DCE 1.2, DCE(cis), CCl₄ 1.1, TCA, and TCE.

Organic chemical concentrations have been modeled to reflect remediation activities at OU 1 using groundwater monitoring results and the knowledge of hydrogeological conditions. The results of groundwater modeling of the chemicals indicate that Alternative 5 would comply with Basic Standards for Groundwater 10 years after implementation of remediation, assuming the French Drain is in place. The French Drain location would achieve the State Basic Standards after the 10th year, with the exception of TCE, according to the modeling results. However, the steady state model assumes the source of contamination remains during the period of remediation. Contaminants at the location of Woman Creek would comply with the State

Groundwater Standards sooner than 10 years after remediation Assumptions of the model and results of the model are discussed in Appendix B

Action Specific ARARs

Some contaminants would be left in place at the IHSSs (other than 119 1) within OU 1 The sources at IHSS 119 would be remediated to reduce contaminant concentrations Collection of the mobile contaminants in groundwater at the French Drain and subsequent treatment of contaminants in the water treatment system would continue for as long as is necessary to achieve the State groundwater standards There is a potential for some contaminants to be left in place at some of the IHSSs since groundwater movement is sporadic and subject to climatic conditions

Compliance with 6 CCR 1007 3 264 90 and 264 101 of the State RCRA program is required at OU 1 Compliance with either the RCRA definition of point of compliance or the State groundwater regulatory definition will depend upon the selection of a point of compliance location by EPA CDPHE and DOE

A groundwater monitoring plan would be required for the post-closure period A RCRA performance monitoring system would be implemented with this alternative and would probably be needed for 13 years or more Monitoring of the organic and inorganic constituents would be conducted in accordance with Subpart F of the State RCRA regulations (6 CCR 1007 3 264 93 264 98) Monitoring would be conducted until it is determined that the contaminants are in compliance with the State Basic Standards for Groundwater (5 CCR 1002 8 3 11 5) The state groundwater standards are selected for monitoring since the RCRA regulations do not have protection standards for the contaminants except for selenium

Corrective action would be conducted as long as necessary to achieve the state groundwater standards at the selected point of compliance Maintenance and monitoring of constituents is required to be conducted for 30 years unless the performance monitoring system indicates no exceedances of groundwater standards for three consecutive years and a shortened period of time

is approved by CDPHE. According to the results of the modeling, the required monitoring period is 10 years after source remediation; however, an initial post closure period of 30 years would be initiated with CDPHE. Implementation of this alternative would require a determination by CDPHE that the corrective action is protective of human health and the environment. The point of compliance for the performance monitoring system would need to be selected to demonstrate compliance with the RCRA corrective action requirements and the groundwater protection standard (Subpart F).

Subsurface soils at OU 1 contain listed hazardous wastes and are potentially regulated under Subtitle C of RCRA. Delisting of the treated soils at OU 1 is a potential option as the treated soil should meet the RCRA delisting requirements in *A Guide to Delisting of RCRA Wastes for Superfund Remedial Responses* (OSWER # 9347 3-09FS). Delisting of the treated soils would allow disposal of the soils on site. The delisting process can require two years of agency review and approval.

Site specific treatability study data may become available from other OUs in the future. Data provided by the supplier of the thermal desorption unit shows that treatment of similar wastes has resulted in constituent levels below the delisting criteria, the Maximum Allowable Concentrations (MACs). The constituents found in the subsurface soil that are listed wastes are

- carbon tetrachloride
- tetrachloroethene
- 1,1,1 trichloroethane
- trichloroethene
- toluene
- xylenes

The treated soil should pose no significant threat to groundwater and would be fully protective of human health and the environment.

Verification testing in all likelihood would need to be performed after treatment to confirm delisting levels. The verification testing would include analysis for total and TCLP leachate.

concentrations Verification testing would be performed using the appropriate QA/QC procedures

It is possible that EPA's proposed definition and treatment standards for hazardous soil could be promulgated prior to the final CAD/ROD. It is anticipated that this alternative should meet any changes to the definition and treatment standards for hazardous soil. Other action specific ARARS such as the Colorado Water Quality Control Act effluent limitations and stormwater regulations should be complied with during the remedial activities. The State's air pollution regulations should not be an ARAR since there are no technologies or facilities at OU 1 which could be a source of emissions.

Location Specific ARARS

Dewatering will involve placing a PVC pipe from the excavation to the French Drain. Although the construction area involved in the activity would be small, there may be a short term impact to riparian and wetland areas around the French Drain. Mitigation measures will be used to minimize the disruption; however, any destroyed riparian areas will be replaced or created according to DOE wetland regulations.

Alternative 5 may result in adverse effects to threatened and endangered species or species of special concern at the site. Mitigation measures will be discussed with the CDOW to minimize habitat disruption and to comply with regulations for species such as the Preble's meadow jumping mouse. Should the mouse become a Federally protected species, consultation with the U.S. Fish and Wildlife Service will be initiated to comply with Section 7 of the Endangered Species Act.

4.3.6.3 Long Term Effectiveness and Permanence

The excavation to bedrock and dewatering components of Alternative 5 will significantly reduce potential risks to human health and the environment by removing contaminated groundwater and

subsurface soil The French Drain and Building 891 water treatment system will continue to extract and treat contaminated groundwater until concentrations at the IHSS are reduced below the PRGs Groundwater modeling indicates that the contaminated groundwater should be removed after 10 years Because groundwater models are based on assumptions rather than known quantities at a site an additional 3 years of monitoring will be conducted to achieve the groundwater PRGs

The carcinogenic risks for the French Drain and Woman Creek are below the acceptable risk range of 10^{-4} to 10^{-6} because the contaminated soil and groundwater are removed from the treatment area The noncarcinogenic hazard indices associated with the French Drain and Woman Creek do not indicate a potential for adverse effects to human health

Following treatment of the primary contaminant source contaminated groundwater within OU 1 may continue to migrate away from IHSS 119 1 Modeling indicates that because of the French Drain and the source removal groundwater should meet PRGs for the contaminants at Woman Creek thereby providing long term effectiveness and minimizing human health risks

Alternative 5 should provide a high degree of permanence if the sources at IHSS 119 1 are fully remediated Uncertainties regarding the nature and extent of the DNAPL sources may limit the degree of permanence achieved by the alternative A 5 year review should be conducted to determine the effectiveness of this alternative

To further provide long term protection and minimize human health risk excavated soil will be managed according to applicable regulations and treated to below LDR standards or levels of concern Disposal will be at a permitted TSD facility with the possibility of on site disposal if approved by CDPHE through the petition process There should be no significant risks associated with handling nonradioactive treated soil

4 3 6 4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 5 satisfies the NCP preference for treatment as a principal element of an alternative

It should effectively and irreversibly reduce the mobility and volume of contaminants in OU 1 by removing the primary source of contaminants from the subsurface and groundwater. Excavating an estimated 17 500 cubic yards of soil within the treatment zone will reduce the volume of contaminants in subsurface soil in both the saturated and unsaturated zones. Removing the source of the contaminants will also reduce contaminant mobility by preventing potential migration. Dewatering the treatment area of an estimated 80 000 gallons of groundwater will reduce the contaminant volume and mobility.

Treating the contaminated soil will reduce the contaminant volume and toxicity in the soil prior to disposal at a properly permitted TSD facility or potentially onsite. In addition, extracted groundwater will be treated using the UV/H₂O₂, ion-exchange, and GAC processes in the Building 891 water treatment system. UV/H₂O₂ is a destructive and irreversible process and will decrease contaminant toxicity.

Wastes generated as a result of this alternative include regenerant solution from ion exchange resins and GAC from the Building 891 water treatment system, treated soil, and wastes from well installation such as drill cuttings and decontamination water. The secondary wastes produced during treatment and the processes used to treat these wastes include:

- Regeneration of the ion-exchange resins resulting in a solution that will be treated at the Building 374 Evaporator
- Spent GAC that will be sent offsite for regeneration
- Decontamination water that will be sent to Building 891 for treatment by the UV/H₂O₂ and ion exchange processes
- The treated soil and wastes such as drill cuttings will be managed according to applicable regulations before being transported to a permitted TSD facility

There should be no significant risks associated with handling the wastes or shipping nonradioactive treated soil.

4 3 6 5 Short Term Effectiveness

Protection of human health and the environment should begin shortly after the excavation is completed for Alternative 5. However, the alternative may have significant short term impacts on human health and the environment such as potential worker and public health exposure to fugitive dust created during the excavation, transportation, and storage of excavated soil. Additional short term effects include the displacement or destruction of vegetation.

Alternative 5 will have a significant short term impact on the immediate environment due to the large excavation and material transportation requirements. Excavating the contaminant source area will adversely impact the site flora, fauna, and subsurface biota. Mitigation measures will be used to minimize the impact.

During implementation of Alternative 5, there may be a risk to the public due to potentially contaminated dust generated during the excavation, transportation, and storage of large quantities of surficial and subsurface soil. Management of the soil will comply with 40 CFR Part 122.26 Part 264 and DOE orders. Stormwater controls would be employed to reduce runoff at the site. Methods such as creating a three-sided building with a roof or other cover for storage areas to minimize fugitive dust will assist in minimizing exposure risks. There may be potential risks to workers from exposure to contaminants in groundwater, soil, or fugitive dust. Workers may also encounter safety hazards associated with operating excavation/backfill equipment and the thermal desorption unit. Risks to workers will be minimized through standard health and safety practices.

Although surface soils are being administratively addressed under OU 2, radionuclides are a short term effectiveness concern under this alternative due to the potential for exposure to both on-site and off-site receptors from fugitive dust. Excavation activities would increase the resuspension of radionuclides in surface soils, thereby increasing off-site exposure point source terms as well as the flux of contaminants to Woman Creek.

Groundwater modeling for Alternative 5 indicates that the peak concentrations at Woman Creek are below the PRGs at OU 1 for all of the contaminants except TCE. The actual peak concentrations should be less than the modeled concentrations because the model assumed that the French Drain will be decommissioned when the alternative is implemented. Therefore ecological receptors at Woman Creek should not be affected by OU 1 groundwater contaminants under this alternative. Woman Creek is an intermittent stream which may have a greater effect on ecological receptors because of a lack of water than the peak contaminant concentrations.

4.3.6.6 Implementability

Alternative 5 will not limit the use of future remedial actions at the site if they are deemed necessary. In addition, thermal desorption is a proven soil remediation technology that should not involve administrative difficulties. Alternative 5 should not be limited by the availability of services and materials. There may be significant technical or administrative difficulties if Preble's meadow jumping mouse is designated a Federally protected Threatened/Endangered species. Such a designation would require consultation under Section 7 of the Endangered Species Act. Protection of human health and the environment should begin shortly after the excavation is complete.

It is anticipated that 3 months will be required to mobilize and demobilize the thermal desorption unit. Standard equipment will be used for excavating the contaminated soil at IHSS 119.1. A large storage area may be required for stockpiling and treating the excavated soil but it is expected that sufficient space will be available adjacent to the excavation area. The Treated soil may be delisted as a hazardous waste to allow onsite disposition. However, the process of delisting could require two years. In addition, for offsite disposal, the number of TSD facilities that will accept the subsurface soil may be limited if it contains radioactive material.

Air monitoring will be required during the operation of the thermal desorption unit and radiological monitoring will be conducted throughout the remediation. Groundwater monitoring will be conducted for 13 years after remediation is complete to achieve the groundwater PRGs.

4 3 6 7 Cost

Costs for Alternative 5 include the following items

- Construction of a staging area
- Use of conventional soil excavation and backfill equipment
- Four new groundwater monitoring wells
- Operation and mobilization/demobilization of a thermal desorption unit
- Disposal of nonradioactive treated soil at a permitted TSD facility
- Operation of the building 891 treatment system
- Groundwater monitoring

The total capital cost for Alternative 5 is \$9 034 500 The total O&M cost is \$3,113 000 including operation of the Building 891 treatment system for 10 years following the completion of excavation The total post-closure cost is \$1 122 100 including groundwater monitoring for 13 years following completion of remediation The total cost of this alternative is \$13,269,600 A detailed cost estimate is included in Appendix A

4 4 Comparative Analysis of Alternatives

This section presents the comparative analysis of alternatives in relation to the specific RCRA/CERCLA evaluation criteria The results of the detailed analysis of alternatives is summarized in Table 4 2 This information is used to compare alternatives in the following subsections

4 4 1 Overall Protection of Human Health and the Environment

The overall protection of human health and the environment is highest with Alternative 1 because of its low overall risk to human health and the environment while providing irreversible groundwater extraction and treatment Alternative 1 should result in no significant change in protection of human health and the environment Alternatives 2 3 and 4 currently offer the same verifiable protection as Alternative 1 because the locations of DNAPL sources are

unknown Alternative 5 provides irreversible treatment and the largest reduction in exposure potential within the shortest time However it also has the greatest adverse effects to the environment and workers

Alternatives 2 3, 4 and 5 reduce the exposure potential by remediating the source of contamination Alternative 1 reduces the exposure potential by containing the source of contamination and limiting access to the site Attaining groundwater cleanup standards a RCRA CAP criteria is also met by Alternatives 1 through 5 Alternative 0 neither meets this criteria nor reduces the exposure potential at the site

Alternative 1 provides the least overall environmental effects of the alternatives because it maintains the current operations at the site and provides containment of the source Alternatives 2 and 3 do not substantially affect the environment but the permanence of SVE depends on knowing the locations of the DNAPL sources which are not well defined at OU 1 Alternatives 3 and 4 affect the environment more than Alternative 2 because of the RF heating units and the mechanical mixer respectively Alternative 5 provides the greatest short term disruption of the environment and the most permanent solution Alternative 0 offers the least permanent solution and greatest long term concern to the environment

The calculated noncarcinogenic hazards do not indicate a potential for adverse human health effects The carcinogenic risks were below the acceptable risk range of 10^{-4} to 10^{-6} for the alternatives except for Alternative 0 Alternative 0 had a carcinogenic risk of 1.2×10^{-5} for an onsite resident Other risks to the public are minimal with the exception of potential fugitive dust created under Alternative 5 by the excavation transportation and storage of potentially contaminated soil

The overall risks to workers at the site include potential exposure to contaminants through groundwater extraction for Alternatives 1 2 3 4 and 5 Workers may be exposed to contaminant vapors for Alternatives 2 3 4 and 5 However calculated carcinogenic and noncarcinogenic effects for workers were below the acceptable risk range for all of these

alternatives Alternatives 3 4 and 5 may expose workers to safety hazards from operating equipment associated with the alternatives In addition Alternative 4 may present safety hazards from potential destabilization of the soil and Alternative 5 may present hazards associated with fugitive dust

Alternative 1 is currently meeting the RAOs for the site Remediation should take less than 2 years for Alternatives 4 and 5 Alternative 3 should remediate the site within 3 years while Alternative 2 is estimated to be 5 years The remediation time for Alternative 0 is difficult to predict but it is assumed that groundwater monitoring will continue for 30 years

4 4 2 Compliance with Applicable or Relevant and Appropriate Requirements

Alternatives 1 5 would comply with the majority of chemical specific, action specific and location specific ARARs The possible exception is the peak concentration of one contaminant TCE which could possibly be above the chemical specific ARAR the Colorado Basic Standards for Groundwater The duration and concentration of the peak is dependent on the alternative and location of the downgradient measured point These observations are based on a review of modeling results It is also possible that the predicted peak concentrations are over estimated and that Alternatives 1 5 or some of these alternatives would not exceed the state groundwater standards Alternative 0 is predicted and in all likelihood would not meet the state groundwater standards

Groundwater modeling results have been used to assist in determining ARAR compliance The two locations used in the simulations of contaminant concentrations are the downgradient side of the french drain and the alluvium at Woman Creek Assumptions of the model include availability of a contamination source even for remediation alternatives through the period 1969 2029 In addition the solubility of TCE in water is relatively high in comparison to the other chemicals used in the model Other modeled steady state flow factors are discussed in Appendix B

The differences in predicted peak concentrations among the alternatives are summarized as follows. Alternative 0 peak concentrations of organics do not comply with the state groundwater standards at the French Drain and peak concentrations of the organics except for TCE might comply with the state groundwater standards at the Woman Creek location after a period of thirty or more years. Alternative 1 peak concentrations of organics would probably comply with the state groundwater standards except for TCE sometime after 2010 at the French Drain location and peak concentrations of organics (including TCE) would probably comply with the state groundwater standards at approximately year 2010 at the Woman Creek location. Alternatives 2-5 peak concentrations of organics would comply with the state groundwater standards with the possible exception of TCE, ten years after remediation is completed at the French Drain. Peak concentrations of organics would comply with the state groundwater standards within ten years and probably sooner of completed remediation at the Woman Creek location.

Compliance with the action specific ARARs are slightly different among the alternatives. Although all the alternatives would be required to comply with the RCRA corrective action and groundwater protection standard, the period of time required to complete corrective action would vary among the alternatives. In addition, CDPHE is required to determine that the selected compliance point and alternative would be protective of human health and the environment. This determination could vary from Alternative 1 to Alternatives 2-5.

The proposed groundwater performance monitoring system would be initiated for thirty years in accordance with the RCRA post closure requirements. However, once the monitoring system indicates no exceedances of groundwater standards for 3 consecutive years, the period of compliance monitoring may be reduced with the approval of CDPHE. Although the period of monitoring is dependent on the selected point to demonstrate compliance, it can be stated that the compliance period would be long for Alternative 0 as compared to Alternative 1 and that the compliance period for Alternative 1 would be relatively long compared to Alternatives 2-5. The monitoring differences would correlate to the differences in time to achieve the State groundwater standards, i.e., Alternative 0 may require 30 or more years of monitoring.

Alternative 1 may require 16 years of monitoring and Alternatives 2-5 may require 10 years or less of monitoring

The other major difference among the alternatives in complying with the action specific ARARs is the air pollution controls required on the vapor extraction systems. Alternatives 2-4 would require compliance with the hazardous organic emission controls under RCRA regulations as well as the State's air pollution control Regulation 7. Alternatives 0 and 1 would not require such compliance as these alternatives do not involve organic compound air emissions.

Compliance with location specific ARARs is one of the major differences among the treatment technology alternatives. The alternative that would require the most mitigation measures in order to comply with the State law on non game species and DOE's regulation on wetlands protection is Alternative 5. This alternative would require placement of a pipeline from IHSS 119.1 to the French Drain. Alternatives 2, 3, and 4 are not anticipated to disrupt wetland areas with the treatment technologies proposed; however, if some areas are disturbed in the implementation of the technology, then compliance with the law and regulations to protect wetland and non game species would be required. All alternatives, including No Action, could disturb a small area of wetlands for a very short time (two to three days) during decommissioning of the French Drain. Mitigation measures would be implemented to minimize the disturbance and comply with the wetland and species protection requirements.

If the Preble's meadow jumping mouse becomes Federally protected as a Threatened/Endangered species, then the compliance requirement for Alternative 5 could be much more elaborate. Consultation with U.S. Fish and Wildlife Service would be required and a biological assessment might need to be prepared.

4.4.3 Long term Effectiveness and Permanence

Alternative 5 offers the most permanent protection of human health and the environment because the primary contaminant source is physically removed and treated. Alternatives 2, 3, and 4 offer

some protection because the source is remediated to the extent possible by the technologies. The degree of permanence depends on the extent that the wells are located next to a DNAPL source. If the wells miss the DNAPL sources, the extraction rate is dependent on the passive partitioning capability of the contaminants. Alternatives 3 and 4 may be more protective than Alternative 2 because they increase volatilization and provide more reduction in the contaminant concentrations. Alternative 1 offers the same protection of human health and the environment as the current conditions because it does not significantly change the current procedures at the site. Alternative 0 offers less protection than is currently available at the site because it decommissions the French Drain which is removing contaminated groundwater. In addition, it does not contain, remediate, or remove the primary source of contamination.

Five year reviews will be conducted for all of the alternatives until contaminant concentrations are consistently below the PRGs and the agencies agree that the site is not a cause for concern. In addition, all of the alternatives require groundwater monitoring to evaluate the site conditions.

Carcinogenic risks and noncarcinogenic hazards are below the acceptable limits for all of the alternatives with the exception of Alternative 0. It indicates a carcinogenic risk for an on site resident of 1.2×10^{-5} at the French Drain which is within the acceptable range of 10^{-4} to 10^{-6} . The carcinogenic risk is 3.3×10^{-8} at Woman Creek under this alternative.

Alternative 5 provides the best long term effectiveness and permanence of the alternatives because it removes and treats the contamination. Alternatives 4, 3, and 2 provide similar permanence and effectiveness; they differ by increasing volatilization capabilities. However, the effectiveness of SVE is dependent on locating the wells near the DNAPL sources and the source locations are currently ill defined. Alternative 1 provides some permanence and effectiveness for the site because it removes and treats groundwater. Alternative 0 provides no permanence nor long term effectiveness except through natural degradation.

4 4 4 Reduction of Toxicity, Mobility, and Volume Through Treatment

Alternatives 2 3 4 and 5 actively remediate the primary source of contamination thereby satisfying the NCP preference for treatment as a principal element of the alternative. Alternatives 2, 3 and 4 use SVE or a variation of it while Alternative 5 uses excavation and thermal desorption. Alternative 1 does not actively remediate the primary source of contamination however it controls it by containing and extracting the contaminated groundwater. Extracted groundwater is then treated in the Building 891 water treatment system. Alternative 0 does not remediate nor control the primary source of contamination. It relies on natural degradation to restore the site.

Alternative 5 provides a greater reduction of TMV than Alternatives 2 3 or 4 because it removes as well as remediates the primary source of contamination. Alternative 5 provides ex situ treatment and disposal of the subsurface soil whereas Alternatives 2 3 and 4 provide in situ treatment of the subsurface soil. Groundwater is removed treated and disposed of for Alternatives 1 2 3 4 and 5.

Alternatives 2 3 and 4 vary according to the enhancement used with SVE. Alternative 2 uses normal SVE. Alternative 3 uses thermally enhanced SVE and Alternative 4 provides thermally enhanced SVE with a mixing action to provide greater soil permeability. Because Alternative 4 increases the soil permeability through homogenous mixing it creates a more hospitable environment for contaminant volatilization than Alternatives 2 or 3. Similarly Alternative 3 will provide more reduction in volume and mobility than Alternative 2 because it provides a better environment for contaminant volatilization.

An irreversible reduction in contaminant toxicity is provided by Alternatives 2 3 and 4 through the use of an off gas treatment system such as a GAC unit for treatment of contaminated soil vapors. Thermal desorption provides a similar reduction in contaminant soil toxicity for Alternative 5. Alternatives 1 through 5 will equally and irreversibly reduce contaminant groundwater toxicity by using the UV/H₂O₂ and ion exchange processes in Building 891.

Alternative 0 reduces contaminant toxicity through natural degradation

Wastes generated for Alternatives 2, 3, 4, and 5 are similar. They include spent GAC and regenerant solution from ion exchange resins in the Building 891 water treatment system, drill cuttings and decontamination water from well installation, and liquid from the SVE liquid/vapor separator. Alternatives 2, 3, and 4 will have additional quantities of spent GAC because of the off gas treatment system for the extracted soil vapors. Treated soil is an additional waste that will have to be managed and disposed of for Alternative 5. Alternative 1 produces wastes associated with the UV/H₂O₂ and ion-exchange processes in building 891 and installation of wells. Alternative 0 produces wastes associated only with well installation.

Alternative 5 is ranked first for reduction in toxicity, mobility, and volume of the contaminants. Alternatives 4, 3, and 2 are ranked second, third, and fourth, respectively, because of their capabilities for extracting contaminated vapors from the soil matrix at IHSS 119.1. Alternative 1 is ranked fifth because it controls the primary source of contamination but does not reduce contaminant soil toxicity, mobility, and volume. It also has a higher possibility than Alternatives 2, 3, and 4 of reverting to the current condition once the remediation is considered complete. Alternative 0 is ranked last because it neither remediates nor controls contamination at OU 1.

4.4.5 Short term Effectiveness

An increase in the protection of human health and the environment is achieved shortly after implementing Alternatives 2, 3, 4, and 5. Alternative 1 provides the same protection of human health and the environment that is currently available at the site. Alternative 0 decreases the current protection of human health and the environment because it will decommission the French Drain and allow potentially contaminated groundwater to migrate from the site.

All of the alternatives will affect the environment when the French Drain is decommissioned. The short term effect may be a loss of wetland acreage, but the expected long term effect is a net gain in wetland acreage. Adverse short term effects to the environment are greatest with

Alternative 5 because of the soil excavation and transportation. It may adversely affect flora, fauna, and biota at the excavation and along the transportation route depending on the mitigation measures used to minimize fugitive dust. Alternative 4 may adversely affect the environment because of the soil mixing. However, it should not affect the environment beyond the immediate treatment area unless it interrupts a major hydrogeological channel or major soil destabilization occurs. Alternative 3 may adversely affect the environment because of the high temperatures that are reached by the RF heating. Depending on the mitigation measures used, the flora and fauna of the area could be affected by a change in soil horizon or biota. Alternative 2 may affect the immediate environment with minor disturbances to the subsurface soil and some vegetative loss during the installation of the SVE system and monitoring wells. Depending on the types of institutional controls that are selected, Alternative 1 may have the same minimal effects to the environment as Alternative 0. Alternative 0 is expected to affect the environment through the French Drain decommission and monitoring well installation. Ecological receptors at Woman Creek should not be significantly affected by the alternatives except for Alternative 5.

Groundwater modeling indicates that the contaminant concentrations at points directly upgradient of Woman Creek meet the surface water standards with the possible exception of TCE. The actual concentrations for Alternatives 1 through 5 should be less than the modeled concentrations because the model assumed that the French Drain would be immediately decommissioned rather than 10 years after remediation as suggested within the alternatives.

Alternative 5 will affect human health by creating fugitive dust from the excavation, transportation, and storage of subsurface soil. Mitigation measures will be used to minimize the dust. Short term effects on human health are minimal for Alternatives 1, 2, 3, and 4. There should be no additional short term effects on human health for Alternative 0.

Alternatives 2, 3, 4, and 5 may affect workers through exposure to contaminants in groundwater, soil vapor, and operation of the remediation and well installation equipment. Alternative 5 will also affect workers by creating fugitive dust during excavation, transportation,

and storage of contaminated soil. Alternative 4 may create an additional hazard for workers by decreasing the stability of the soil matrix. Alternative 1 has the potential to affect workers only through exposure to contaminants in groundwater. Because there is no source control or remediation for Alternative 0, there should be no additional risks to workers.

The short term risks are expected to be greatest for Alternatives 5, 4, and 3. Alternative 2 should have minimal risks and Alternative 0 and 1 should have no additional risks.

4.4.6 Implementability

None of the alternatives should limit future remediation if it is deemed necessary by the regulatory agencies. In addition, Alternatives 0, 4 are not expected to have administrative difficulties before the alternatives can be implemented at the site. Alternative 5 may require additional lead time for agency approvals in either a RCRA delisting process or Endangered Species Act consultation process.

Groundwater monitoring is required for all of the alternatives as long as the contaminant concentrations are above the PRGs and the agencies believe there is a cause for concern at the site. Vapor monitoring will be conducted for Alternatives 2, 3, and 4 to optimize the SVE system and determine replacement rates for the GAC units. Vapor and radiological monitoring will be conducted for Alternative 5 to indicate health risks to workers.

There may be technical problems with Alternatives 2, 3, and 4. For SVE and groundwater extraction to be effective, the wells should be located near or in the DNAPL source. Otherwise, the technology is dependent on the passive partitioning capability and rate of the compound. In addition, the mechanical mixer in Alternative 4 homogenizes the soil, which can decrease the cohesiveness of the soil. The decreased cohesion may result in instability, slumping, and decreased traction for getting to the site and installing groundwater monitoring and extraction wells. Alternative 4 may also require special training to operate the mixing equipment because of the proprietary technology. Alternative 3 may require special training from the vendor on

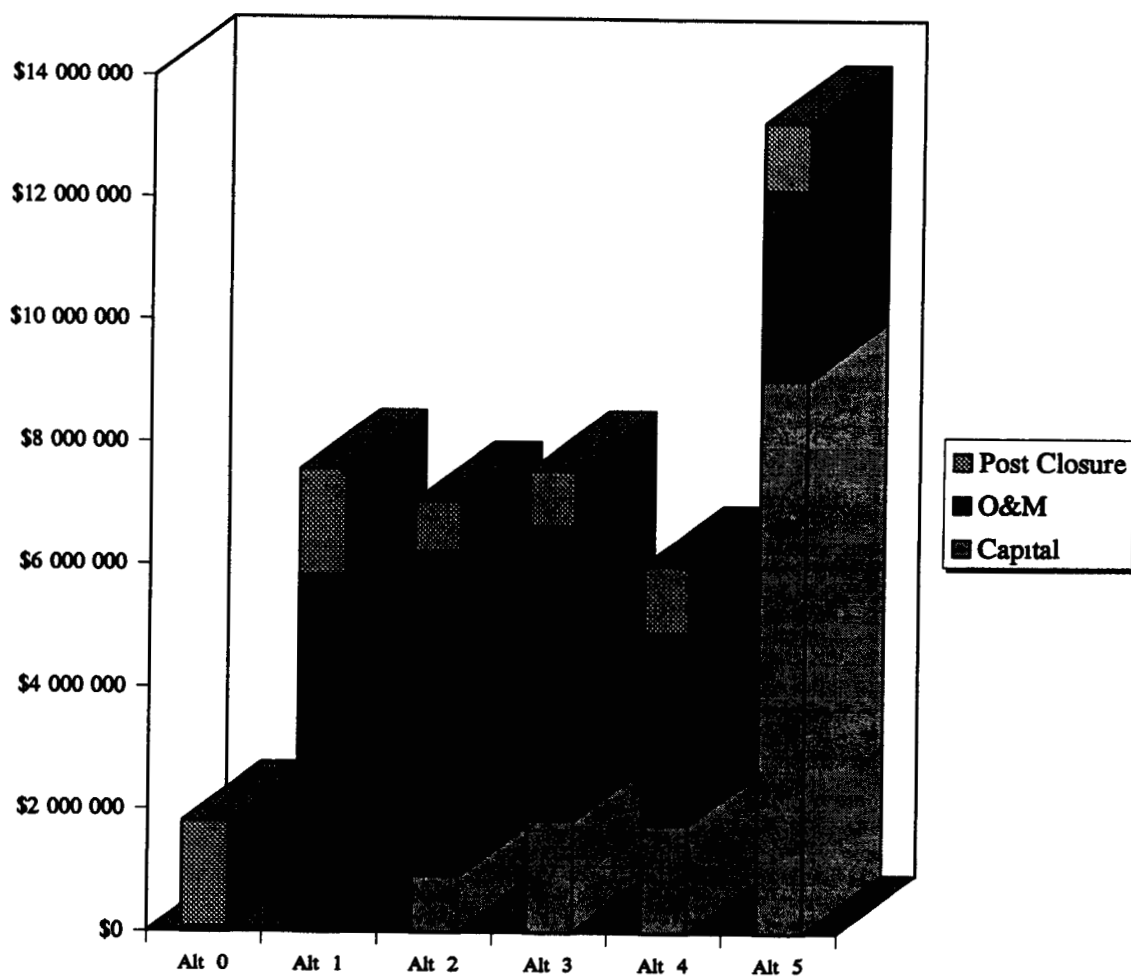
operation of the RF antennae before it can be implemented

Alternatives 0 and 1 can be implemented immediately while the remaining alternatives may require 6 months before they can begin treatment of the primary contaminant source. Alternative 3 is available through specialized vendors and Alternative 4 is a proprietary treatment; the lead time necessary before treatment can begin for these alternatives may be longer than the original estimation.

Because of the lack of lead time necessary for implementation, Alternatives 0 and 1 are expected to be the easiest to implement of the alternatives. Alternative 0 can be implemented immediately once it is approved; however, it is not expected to be easily approved because of the nature of the site. Alternatives 2 and 5 should be easily implemented but may require a six month lead time. Alternatives 3 and 4 may require specialized training and additional lead time to procure the equipment from vendors. Alternative 5 could require substantial time to implement because of two facts: 1) If the Preble's meadow jumping mouse becomes Federally protected, the consultation process under the Endangered Species Act will be required. The process could require a biological assessment in addition to mitigation measures. 2) Soils which are treated could be delisted under RCRA for onsite disposal. The delisting process could require two years for agency review and approval.

4.4.7 Cost

The total costs for the alternatives are listed in Figure 4.1. Alternative 5 has the largest cost primarily because of the large volume of soil that would require excavation, treatment, and disposal. The costs for Alternatives 1 and 3 are comparable. Alternative 2's cost was less than Alternatives 5, 1, and 3. Alternative 4 has higher capital costs but due to the higher O&M cost of SVE, Alternative 2 has a higher total cost than Alternative 4. Alternative 0 was the least expensive because it involved only the installation of monitoring wells and the associated monitoring activities.



Cost Element	Alt 0	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
Capital	\$63 800	\$63 800	\$925 600	\$1 843 600	\$1 781 400	\$9 034 500
O&M	\$0	\$5 761 200	\$5 287 700	\$4 798 200	\$3 113 000	\$3 113 000
Post Closure	\$1 740 400	\$1 740 400	\$833 300	\$918 700	\$1 120 700	\$1,122 100
Total Cost	\$1 804 200	\$7,565 400	\$7 046 600	\$7 560 500	\$6 015 100	\$13 269 600

Note Costs represent 1995 dollars at 5% discount rate

Figure 4-1 Summary of Remedial Action Alternative Costs

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Table A 1 Alternative 0 No Action

Activity	Resource Description	Qty	Unit	Bare Costs Per Unit				Source	Bare Costs				Total Costs	
				Mat 1	Equip.	Labor	Sub-contract		Mat 1	Equip.	Labor	Sub-contract		
Direct Capital Costs														
Drill Monitoring Wells	Drill & Case 4 wells 6 diam & 20 dept	4	ea					\$10 000 00	Prof Judgement	\$0	\$0	\$0	\$40 000	\$40 000
Field Personnel	Surveyor	8	hr				\$50 00		Prof Judgement	\$0	\$0	\$400	\$0	\$400
	Health & Safety	8	hr				\$65 00		Prof Judgement	\$0	\$0	\$520	\$0	\$520
	Geologist	40	hr				\$55 00		Prof Judgement	\$0	\$0	\$2 200	\$0	\$2 200
Subtotal Direct Capital Costs										\$0	\$0	\$3 120	\$40 000	\$43 120
Indirect Capital Costs														
Misc Labor & Materials	10% of direct labor & \$1 50 in materials cost for each direct labor hour								Facil Eng 009	\$84	\$0	\$312	\$0	\$396
Permits	5% of direct materials equipment & labor								Prof Judgement	\$0	\$0	\$156	\$0	\$156
Construction Management	10% of direct materials equipment & labor								Prof Judgement	\$0	\$0	\$312	\$0	\$312
Project Management	10% of direct materials equipment & labor								EG&G Cost Est	\$0	\$0	\$312	\$0	\$312
Overhead Profit & Bond	25 3% of direct materials equipment & labor								Facil Eng 009	\$0	\$0	\$789	\$0	\$789
Subcontractor Fee	10% of subcontractor costs								Facil Eng 009	\$0	\$0	\$0	\$4 000	\$4 000
Subtotal Indirect Capital Costs										\$84	\$0	\$1 881	\$4 000	\$5 965
Contingency	30% of direct and indirect capital costs								Facil. Eng. 009	\$25	\$0	\$1 500	\$13 200	\$14 726
Total Capital Costs										\$109	\$0	\$6 502	\$57 200	\$63 811

Annual O&M Direct Costs												
Subtotal O&M Direct Costs									\$0	\$0	\$0	\$0
Total O&M Costs												
									\$0	\$0	\$0	\$0

Annual Post Closure Direct Costs												
Semiannual Sampling	Collect Groundwater Samples	12	ea				\$1 500 00	Prof Judgement	\$0	\$0	\$0	\$18 000
Analytical Work	Sample Analysis for VOCs & Inorganics	14	ea				\$4 100 00	Vendor Quote	\$0	\$0	\$0	\$57 400
Subtotal Post Closure Direct Costs												
									\$0	\$0	\$0	\$75,400
Annual Post Closure Indirect Costs												
Project Management	10% of post closure direct material equipment & labor costs							EG&G Cost Est	\$0	\$0	\$0	\$0
Subcontractor Fee	10% of post closure subcontractor costs							Facil Eng 009	\$0	\$0	\$0	\$7 540
Subtotal Post Closure Indirect Costs												
									\$0	\$0	\$0	\$7 540
Contingency	30% of total post closure direct and indirect costs							Facil. Eng. 009	\$0	\$0	\$0	\$24 882
Total Annual Post Closure Costs												
									\$0	\$0	\$0	\$107,822

Activity	Resource Description	Qty	Unit	Bare Costs Per Unit				Source	Bare Costs				Total Costs	
				Mat 1	Equip.	Labor	Sub-contract		Mat 1	Equip.	Labor	Sub-contract		
Total Post Closure Costs (30 yrs @ 5% discount rate)														
										\$0	\$0	\$0	\$1 740 363	\$1 740 363

Total Cost Of Alternative													
									\$109	\$0	\$6,502	\$1,797,563	\$1,804,174

Table A 2 Alternative 1 Institutional Controls With the French Drain

Activity	Resource Description	Qty	Unit	Bare Costs Per Unit				Bare Costs				Total Costs	
				Mat'l	Equip.	Labor	Sub-contract	Mat'l	Equip.	Labor	Sub-contract		
Direct Capital Costs													
Drill Monitoring W lls	Drill & Case 4 w lls 6 diam & 20 depth	4	ca				\$10 000 00	Prof Judgement	\$0	\$0	\$0	\$40 000	\$40 000
F lld Personnel	Survey	8	hr				\$50 00	Prof Judgement	\$0	\$0	\$400	\$0	\$400
	Health & Safety	8	h				\$65 00	Prof Judgement	\$0	\$0	\$520	\$0	\$520
	Geol gnt	40	hr				\$55 00	Prof Judgement	\$0	\$0	\$2,200	\$0	\$2,200
Subtotal Direct Capital Costs												\$43,120	
Indirect Capital Costs													
Misc Labo & Materials	10% of direct labor & \$1 50 materials cost for each direct labor h ur							Facil Eng 009	\$84	\$0	\$312	\$0	\$396
Permits	5% f direct materials equ pment & labor							Prof Judgement	\$0	\$0	\$156	\$0	\$156
Constructi Managem nt	10% f direct materials equipment & labo							Prof Judgement	\$0	\$0	\$312	\$0	\$312
Project Manag ement	10% f d rect materials equipment & labor							EG&G Cost Est	\$0	\$0	\$312	\$0	\$312
Overhead Profit & Bond	25 3% f d rect materials, equ pment, & labor							Facil Eng 009	\$0	\$0	\$789	\$0	\$789
Subcontracto Fee	10% f subcontracto costs							Facil Eng 009	\$0	\$0	\$0	\$4 000	\$4 000
Subtotal Indirect Capital Costs												\$5 965	
Contingency	30% of direct and indirect capital costs							Facil Eng 009	\$25	\$0	\$1,500	\$13,200	\$14 726
Total Capital Costs												\$63,811	

Annual O&M Direct Costs												
Groundwater Treatment	Building 891 Water Treatment System	1	y				\$249 600 00	(1)	\$0	\$0	\$249 600	\$249 600
Subtotal O&M Direct Costs												\$249,600
Annual O&M Indirect Costs												
Misc Labo & Materials	10% f d rect labo & \$1 50 n material cost for each direct labo hour								\$0	\$0	\$0	\$0
Project Management	10% f direct materials equ pment & labor costs								\$0	\$0	\$0	\$0
Overhead Profit & Bond	25 3% f direct materials equ pment & labor costs								\$0	\$0	\$0	\$0
Subcontracto Fee	10% f subcontractor costs								\$0	\$0	\$24 960	\$24 960
Subtotal O&M Indirect Costs												\$24,960
Contingency	30% of total direct and indirect O&M costs								\$0	\$0	\$82,368	\$82,368
Total Annual O&M Cost												\$135,928
Total O&M Costs (30 yrs @ 5% discount rate)												\$5 761,261

Annual Post Closure Direct Costs												
Semiannual Sampling	Collect Groundwater Samples	12	ca				\$1 500 00	Prof Judgement	\$0	\$0	\$18 000	\$18 000
Analys al W rk	Sampl Analysis for VOCs & Inorganics	14	ca				\$4 100 00	Vendor Quote	\$0	\$0	\$57 400	\$57 400

Activity	Resource Description	Qty	Unit	Bare Costs Per Unit				Bare Costs				Total Costs
				Mat'l	Equip.	Labor	Sub-contract	Mat'l	Equip.	Labor	Sub-contract	
Subtotal Post Closure Direct Costs												
Annual Post Closure Indirect Costs												
Project Management	10% of post closure direct materials equipment & labor costs							EG&G Cost Est	\$0	\$0	\$0	\$0
Subcontract Fee	10% of post closure subcontract costs							Facil Eng 009	\$0	\$0	\$0	\$7,540
Subtotal Post Closure Indirect Costs												
Contingency	30% of total post closure direct and indirect costs							Facil Eng 009	\$0	\$0	\$0	\$24,882
Total Annual Post Closure Costs												
									\$0	\$0	\$0	\$107,822
Total Post Closure Costs (30 yrs @ 5% discount rate)												
									\$0	\$0	\$0	\$1,740,363

Total Cost Of Alternative												
												\$7,565,375

(1) Letter from Kim R. Ger Group 1 Closures Building 080 to Zake Houk Group 1 Closures Building 080 December 21 1994

Table A 3 Alternative 2 Groundwater Pumping With Soil Vapor Extraction

Activity	Resource Description	Qty	Unit	Bare Costs Per Unit				Source	Bare Costs				Total Costs
				Mat 1	Equip	Labor	Sub-contract		Mat 1	Equip	Labor	Sub-contract	
Direct Capital Costs													
Soil Gas Survey	Geologist	120	hr					Prof Judgement	\$0	\$0	\$6 600	\$0	\$6 600
	Field Technician	80	hr					Prof Judgement	\$0	\$0	\$2 800	\$0	\$2 800
	Portable GC	2	wk		\$1 000 00			Prof Judgement	\$0	\$2 000	\$0	\$0	\$2 000
	Probes Pump and Misc Equipment	100	ea		\$15 00			Prof Judgement	\$0	\$1 500	\$0	\$0	\$1 500
Dewatering	Drill Extraction Wells, 6 diam 20 ft depth	3	ea				\$10 000 00	Prof Judgement	\$0	\$0	\$0	\$30 000	\$30 000
	10 gpm submersible pump	3	ea		\$300 00			Vendor Quote	\$0	\$900	\$0	\$0	\$900
	PVC Piping to French Drain Sump 2 5	600	lf	\$1 70				Means Ref	\$1 020	\$0	\$1 314	\$0	\$2 334
SVE System	Drill & Install Casing for Vapor Extraction	36	ea				\$10 000 00	Prof Judgement	\$0	\$0	\$0	\$360 000	\$360 000
	Wells 4 diam & 20 depth	3	ea				\$5 280 00	Vendor Quote	\$0	\$0	\$0	\$15 840	\$15 840
	Vapor Extraction System	600	lf	\$3 41				Means Ref	\$2 046	\$0	\$1 662	\$0	\$3 708
	4 PVC Piping Including Fitting	40	lf	\$5 25				Means Ref	\$210	\$0	\$112	\$0	\$322
	6 PVC	42	ea	\$300 00				Vendor Quote	\$12 600	\$0	\$2 100	\$0	\$14 700
	4 Butterfly Valves PVC	36	ea				\$1 500 00	Vendor Quote	\$0	\$0	\$0	\$54 000	\$54 000
	Manhole	36	ea				\$150 00	Vendor Quote	\$0	\$0	\$0	\$5 400	\$5 400
	Vacuum Gages	6	ea				\$2 000 00	Vendor Quote	\$0	\$0	\$0	\$12 000	\$12 000
	Flow Element/Local Indicator	320	sq ft					Prof Judgement	\$0	\$0	\$0	\$8 000	\$8 000
	Shed Housing SVE Pump & Carbon	1	ea		\$350 00			Vendor Quote	\$0	\$350	\$0	\$0	\$350
	Adsorption Equipment	1	ea					Vendor					
	Electric Heater	1	ls	\$1 650 00	\$575 00	\$368 00		Quote/Means	\$1 650	\$575	\$368	\$0	\$2 593
Installation of Equipment	Geotextile Lane (10 000 ft ²)	96	hrs					Prof Judgement	\$0	\$0	\$3 360	\$0	\$3 360
	Installation Mechanical & Electrical	1	ls	\$400 00				Prof Judgement	\$400	\$0	\$0	\$0	\$400
Off-gas Treatment	Carbon Adsorption System	2	ea		\$5 218 00			Vendor Quote	\$0	\$10 436	\$0	\$0	\$10 436
	Initial Granular Activated Carbon (3 000 lb.)	1	ls	\$3 240 00				Vendor Quote	\$3 240	\$0	\$0	\$0	\$3 240
Drill Monitoring W II	Drill & Case 4 w 1ls 6 diam & 20 depth	4	ea				\$10 000 00	Prof Judgement	\$0	\$0	\$0	\$40 000	\$40 000
Additional Field Personnel	Surveyor	80	hr					Prof Judgement	\$0	\$0	\$4 000	\$0	\$4 000
	Health & Safety/Rad Monitoring	80	hr					EGG Rad Eng	\$0	\$0	\$5 200	\$0	\$5 200
	Maintenance of Rad Monitoring Equip	10	hr					EGG Rad Eng	\$0	\$0	\$550	\$0	\$550
	Geologist	24	hr					Prof Judgement	\$0	\$0	\$1 320	\$0	\$1 320
SVE Well Closure (I)	Labor	400	hr					Prof Judgement	\$0	\$0	\$10 903	\$0	\$10 903
	Bentonite Grout W II	9 30	CY	\$54 00				Vendor Quote	\$391	\$0	\$0	\$0	\$391
Subtotal Direct Capital Costs									\$21 557	\$15 761	\$40 290	\$525 240	\$602 648
Indirect Capital Costs													
Eng Design & Inspection	15% of direct materials equipment, & labor							Facil Eng 009	\$3 234	\$2 364	\$6 043	\$0	\$11 641
Misc Labor & Materials	10% of direct labor & \$1 50 m materials cost for each direct labor hour							Facil Eng 009	\$780	\$0	\$4 029	\$0	\$4 809
Permits	5% of direct materials equipment, & labor							Prof Judgement	\$1 078	\$788	\$2 014	\$0	\$3 880
Construction Management	10% of direct materials equipment, & labor							Prof Judgement	\$2 156	\$1 576	\$4 029	\$0	\$7 761

Activity	Resource Description	Qty	Unit	Bare Costs Per Unit				Source	Bare Costs				Total Costs
				Mat 1	Equip	Labor	Sub-contract		Mat 1	Equip	Labor	Sub-contract	
Project Management	10% of direct materials equipment, & labor + BD&I							EG&G Cost Est.	\$2 479	\$1 813	\$4,633	\$0	\$8 925
Overhead Profit & Bond	25 3% f direct materials equipment, & labor							Facil Eng 009	\$5 454	\$3 988	\$10 193	\$0	\$19 635
Subcontractor Fee	10% f subcontractor costs							Facil Eng 009	\$0	\$0	\$0	\$52 524	\$52 524
Subtotal Indirect Capital Costs													
									\$15 180	\$10 528	\$30 942	\$52 524	\$109 175
Contingency	30% of direct and indirect capital costs							Facil Eng 009	\$11,021	\$7 887	\$21,370	\$173,329	\$213 607
Total Capital Costs													
									\$47 758	\$34 176	\$92,602	\$751 093	\$925,629

Annual O&M Direct Costs													
Operations	Replacement Granular Activated Carbon	12,000	lb	\$1 08			\$1 25	Vendor Quote	\$12 960	\$0	\$15 000	\$0	\$27 960
	Transportation of Spent GAC	4	loads					Vendor Quote	\$2,700 00	\$0	\$0	\$10 800	\$10 800
	Disposal of Granular Activated Carbon	12 000	lb					Vendor Quote	\$0 34	\$0	\$0	\$4 080	\$4 080
	Electrical Costs of Vacuum Pump	36	wk	\$47 00				Prof Judgement	\$1,692	\$0	\$0	\$0	\$1 692
	Electrical Costs of Heater	24	wks	\$23 63				Prof Judgement	\$567	\$0	\$0	\$0	\$567
	Confirmatory Sampling	80	ea					Prof Judgement	\$0	\$0	\$0	\$12 000	\$12 000
	Groundwater Treatment @ Building 891												
	Treat. System	1	yr					(2)	\$0	\$0	\$0	\$249 600	\$249 600
Semiannual Sampling	Collect Groundwater Samples	12	ea					Prof Judgement	\$0	\$0	\$0	\$18 000	\$18 000
	Sample Analysis for VOC & Inorganics	14	ea					Vendor Quote	\$0	\$0	\$0	\$57 400	\$57 400
	Collect & Analyze Vapor Samples	12	ea					Prof Judgement	\$0	\$0	\$0	\$12,000	\$12,000
Maintenance	Labor	192	hr				\$35 00	Prof Judgement	\$0	\$0	\$6 720	\$0	\$6 720
	Materials & Parts	12	mo	\$200 00				Prof Judgement	\$2 400	\$0	\$0	\$0	\$2,400
Personnel	Operator	2,080	hr				\$35 00	Prof Judgement	\$0	\$0	\$72 800	\$0	\$72 800
	H&S	96	hr				\$65 00	Prof Judgement	\$0	\$0	\$6 240	\$0	\$6,240
	Geologist	192	hr				\$55 00	Prof Judgement	\$0	\$0	\$10,560	\$0	\$10,560
Subtotal O&M Direct Costs													
									\$17,619	\$0	\$111,320	\$363,880	\$492,819

Annual O&M Indirect Costs													
Misc Labor & Materials	10% of direct labor & \$1 50 in material cost for each direct labor hour							Facil Eng 009	\$3 840	\$0	\$11 132	\$0	\$14 972
Project Management	10% of direct materials, equipment, & labor costs							EG&G Cost Est.	\$1,762	\$0	\$11 132	\$0	\$12 894
Overhead, Profit & Bond	25 3% of direct materials equipment, & labor costs							Facil Eng 009	\$4,458	\$0	\$28 164	\$0	\$32 622
Subcontractor Fee	10% of subcontractor costs							Facil Eng 009	\$0	\$0	\$0	\$36 388	\$36,388
Subtotal O&M Indirect Costs													
									\$10 060	\$0	\$50 428	\$36,388	\$96,875
Contingency	30% of total direct and indirect O&M costs							Facil Eng 009	\$8,304	\$0	\$48 524	\$120 080	\$176,908
Total Annual O&M Cost													
									\$35 982	\$0	\$210,272	\$520,348	\$766,603
Total O&M Costs (expenditures occur in yrs 2-5 @ 5% discount rate) (3)													
									\$127,591	\$0	\$745,615	\$4,414,454	\$5,287,660

Annual Post Closure Direct Costs													
Semiannual Sampling	Collect Groundwater Samples	12	ea					Prof Judgement	\$1,500 00	\$0	\$0	\$18 000	\$18 000
Analytical Work	Sample Analysis for VOC & Inorganic	14	ea					Vendor Quote	\$4 100 00	\$0	\$0	\$57 400	\$57 400
Subtotal Post Closure Direct Costs													
									\$0	\$0	\$0	\$75,400	\$75,400

Activity	Resource Description	Qty	Unit	Bare Costs Per Unit				Source	Bare Costs				Total Costs
				Mat l	Equip	Labor	Sub-contract		Mat l	Equip.	Labor	Sub-contract	
Annual Post Closure Indirect Costs													
Project Management	10% of post closure direct materials equipment, & labor costs							E&C&G Cost Est.	\$0	\$0	\$0	\$0	\$0
Subcontractor Fee	10% of post closure subcontractor costs							Facil Eng 009	\$0	\$0	\$0	\$7 540	\$7 540
Subtotal Post Closure Indirect Costs									\$0	\$0	\$0	\$7 540	\$7 540
Contingency	30% of total post closure direct and indirect costs							Facil Eng 009	\$0	\$0	\$0	\$24,882	\$24,882
Total Annual Post Closure Costs													
									\$0	\$0	\$0	\$107 822	\$107 822
Total Post Closure Costs (4)													
									\$0	\$0	\$0	\$833,261	\$833,261

Total Cost Of Alternative									\$175,349	\$34,176	\$838,217	\$5,998,808	\$7,046,550
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- (1) Future capital cost that takes place upon completion of treatment. (y 5 @ 5% discount rate total cost is in 1994 dollars)
- (2) Letter from Kam Ruger Group 1 Closures Building 080 to Zak Hook Group 1 Closures Building 080 December 21 1994
- (3) It has been assumed for cost estimating purposes that the Building 891 water treatment system will continue to treat water captured by the French Drain for 10 years following the 4 year SVE period
- The costs for operating the Building 891 treatment system during this time have been included in the total O&M Cost.
- (4) It has been assumed post-closure groundwater monitoring occurs for 13 years following the completion of SVE operation

Table A-4 Alternative 3 Groundwater Pumping and Soil Vapor Extraction With Thermal Enhancement

Activity	Resource Description	Qty	Unit	Bare Costs Per Unit				Source	Bare Costs				Total Costs
				Mat 1	Equip	Labor	Sub-contract		Mat 1	Equip	Labor	Sub-contract	
Direct Capital Costs													
Soil Gas Survey	Geologist	120	hr			\$55 00		Prof Judgement	\$0	\$0	\$6 600	\$0	\$6 600
	Field Technician	80	hr			\$35 00		Prof Judgement	\$0	\$0	\$2 800	\$0	\$2 800
	Portable GC	2	wk		\$1 000 00			Prof Judgement	\$0	\$2 000	\$0	\$0	\$2 000
	Probes Pump and Misc Equipment	100	ea		\$15 00			Prof Judgement	\$0	\$1 500	\$0	\$0	\$1 500
Dewatering	Drill Extraction Wells 6 diam 20 ft depth	3	ea					Prof Judgement	\$0	\$0	\$0	\$30 000	\$30 000
	10 gpm submersible pump	3	ea		\$300 00			Vendor Quote	\$0	\$900	\$0	\$0	\$900
	PVC Piping to French Drain Sump 2.5	600	lf	\$1 70		\$2 19		Means Ref	\$1 020	\$0	\$1 314	\$0	\$2 334
SVE System	Drill & Install Casing for Vapor Extraction Wells 4 diam & 20 depth	36	ea					Prof Judgement	\$0	\$0	\$0	\$360 000	\$360 000
	Vapor Extraction System	3	ea					Vendor Quote	\$0	\$0	\$0	\$15 840	\$15 840
	4 PVC Piping Including Fittings	600	lf	\$3 41		\$2 77		Means Ref	\$2 046	\$0	\$1 662	\$0	\$3 708
	6 PVC	40	lf	\$5 25		\$2 81		Means Ref	\$210	\$0	\$112	\$0	\$322
	4 Butterfly Valves PVC	42	ea	\$300 00		\$50 00		Vendor Quote	\$12 600	\$0	\$2 100	\$0	\$14 700
	Manhole	36	ea				\$1 500 00	Vendor Quote	\$0	\$0	\$0	\$54 000	\$54 000
	Vacuum Gages	36	ea				\$150 00	Vendor Quote	\$0	\$0	\$0	\$5 400	\$5 400
	Flow Element/Local Indicator	6	ea				\$2,000 00	Vendor Quote	\$0	\$0	\$0	\$12 000	\$12 000
	Shed Housing SVE Pump & Carbon Adsorption Equipment	320	sq ft										
	Electric Heater	1	ea		\$350 00		\$25 00	Prof Judgement	\$0	\$0	\$0	\$8 000	\$8 000
RF Heating Unit	Geotextile Lining (10 000ft ²)	1	ls	\$1 650 00	\$575 00	\$368 00		Vendor Quote	\$0	\$350	\$0	\$0	\$350
								Quote/Means	\$1 650	\$575	\$368	\$0	\$2 593
	Setup Startup & Testing	1	ls				\$80 000 00	Vendor Quote	\$0	\$0	\$0	\$80 000	\$80 000
	Equipment Rental	56	wk				\$10 000 00	Vendor Quote	\$0	\$0	\$0	\$560 000	\$560 000
Installation of Equipment	Installation Mechanical & Electrical Materials	96	hrs					Prof Judgement	\$0	\$0	\$3 360	\$0	\$3 360
		1	ls	\$400 00				Prof Judgement	\$400	\$0	\$0	\$0	\$400
Off-gas Treatment	Carbon Adsorption System	2	ea		\$5 218 00			Vendor Quote	\$0	\$10 436	\$0	\$0	\$10 436
	Initial Granular Activated Carbon (3 000 lb)	1	ls	\$3 240 00				Vendor Quote	\$3 240	\$0	\$0	\$0	\$3 240
Drill Monitoring Wells	Drill & Case 4 w 1/2 6 diam & 20 depth	4	ea				\$10 000 00	Prof Judgement	\$0	\$0	\$0	\$40 000	\$40 000
Additional Field Personnel	Surveyor	80	hr			\$50 00		Prof Judgement	\$0	\$0	\$4 000	\$0	\$4 000
	Health & Safety/Rad Monitoring	80	hr			\$65 00		EGG Rad Eng	\$0	\$0	\$5 200	\$0	\$5 200
	Maintenance of Rad Monitoring Equipment	10	hr			\$55 00		EGG Rad Eng	\$0	\$0	\$550	\$0	\$550
	Geologist	24	hr			\$35 00		Prof Judgement	\$0	\$0	\$1 320	\$0	\$1 320
Well Closure (1)	Labor	400	hr			\$35 00		Prof Judgement	\$0	\$0	\$12 050	\$0	\$12 050
	Bentonite Grout Wells	9 30	CY	\$54 00				Vendor Quote	\$432	\$0	\$0	\$0	\$432
Subtotal Direct Capital Costs									\$21,598	\$15,761	\$41,436	\$1,165,240	\$1,244,035

Activity	Resource Description	Qty	Unit	Base Costs Per Unit				Base Costs				Total Costs	
				Mat 1	Equip	Labor	Sub-contract	Source	Mat 1	Equip	Labor		Sub-contract
Total O&M Costs (expenditures occur in years 2 @ 5% discount rate) (3)													
									\$74 447	\$0	\$646,674	\$4,077,097	\$4,796,218

Annual Post Closure Direct Costs															
Seasonal Sampling	Collect Groundw to Samples				12	ea				\$1,500.00	Prof Judgement	\$0	\$0	\$18,000	\$18,000
Analytical Work	Sampl Analy is for VOC & Inorganic				14	ea				\$4,100.00	Vendor Quote	\$0	\$0	\$57,400	\$57,400
Subtotal Post Closure Direct Costs															
												\$0	\$0	\$75,400	\$75,400
Annual Post Closure Indirect Costs															
Project Management	10% of post closure direct materials equipment, & labor costs										EG&G Cost Est.	\$0	\$0	\$0	\$0
Subcontractor Fee	10% of post closure subcontractor costs										Facil Eng 009	\$0	\$0	\$7,540	\$7,540
Subtotal Post Closure Indirect Costs															
												\$0	\$0	\$7,540	\$7,540
Contingency	30% of total post closure direct and indirect costs										Facil Eng 009	\$0	\$0	\$24,882	\$24,882
Total Annual Post Closure Costs															
												\$0	\$0	\$107,822	\$107,822
Total Post Closure Costs (4)															
												\$0	\$0	\$918,670	\$918,670

Total Cost Of Alternative														
										\$122,295	\$34,176	\$741,911	\$6,652,060	\$7,560,442

- (1) Future capital cost that takes place upon completion of treatment. (y = 3 @ 5% discount rate total cost is in 1994 dollars)
- (2) Letter from Kim Rieger Group 1 Closures Building 080 to Zake Houk Group 1 Closures Building 080 December 21, 1994
- (3) It has been assumed for cost estimating purposes that the Building 891 water treatment system will continue to treat water captured by the French Drain for 10 years following the 2 year SVE period
- The costs for operating the Building 891 treatment system during this time have been included in the total O&M Cost.
- (4) It has been assumed that post-closure groundwater monitoring occurs for 13 years following the completion of SVE operation

Table A 5 Alternative 4 Hot Air Injection with Mechanical Mixing

Activity	Resource Description	Qty	Unit	Have Costs Per Unit				Have Costs				Source	Sub-contract	Mat l	Equip.	Labor	Sub-contract	Total Costs
				Mat l	Equip	Labor	Sub-contract	Mat l	Equip.	Labor	Sub-contract							
Direct Capital Costs																		
Soil Gas Survey	Geologist	120	hr			\$55 00			Prof Judgement		\$0	\$0	\$6 600	\$0			\$6 600	\$6 600
	Field Technician	80	hr			\$35 00			Prof Judgement		\$0	\$0	\$2 800	\$0			\$2 800	\$2 800
	Portable GC	2	wk		\$1 000 00				Prof Judgement		\$0	\$2 000	\$0	\$0	\$0		\$2 000	\$2 000
	Probes Pump and Misc Equipment	100	ea		\$15 00				Prof Judgement		\$0	\$1,500	\$0	\$0	\$0		\$1 500	\$1 500
Treatment f Soils	Mechanical Mixing Tool (1)	7 400	cy				\$150 00		Vendor Quote		\$0	\$0	\$0	\$1 110 000			\$1 110 000	\$1 110 000
Additional Field Personnel	Surveyor	80	hr			\$50 00			Prof Judgement		\$0	\$0	\$4 000	\$0			\$4 000	\$4 000
	Health & Safety/Rad Monitoring	480	hr			\$65 00			EGG Rad Eng		\$0	\$0	\$31 200	\$0			\$31 200	\$31 200
	Maintenance of Rad Monitoring Equip	60	hr			\$55 00			EGG Rad Eng		\$0	\$0	\$3 300	\$0			\$3 300	\$3 300
	Geologist	120	hr			\$55 00			Prof Judgement		\$0	\$0	\$6 600	\$0			\$6 600	\$6 600
Drill Monitoring W lls	Drill & Case 4 w lls 6 diam & 20 depth	4	ea				\$10,000 00		Prof Judgement		\$0	\$0	\$0	\$40 000			\$40 000	\$40 000
Extraction Well Closure	Labor	50	hr			\$35 00			Prof Judgement		\$0	\$0	\$1 584	\$0			\$1 584	\$1 584
	Bentonite Grout W lls	0 40	CY	\$54 00					Vendor Quote		\$20	\$0	\$0	\$0			\$20	\$20
Subtotal Direct Capital Costs														\$20	\$3,500	\$56,084	\$1,150,000	\$1,209,603
Indirect Capital Costs																		
Eng Design & Inspection	15% of direct materials, equipment, & labor								Facil Eng 009		\$3	\$525	\$8 413	\$0			\$8 940	\$8 940
Misc Labor & Materials	10% of direct labor & \$1 50 m materials cost for each direct labor hour								Facil Eng 009		\$279	\$0	\$5 608	\$0			\$5 887	\$5 887
Permits	5% of direct materials, equipment, & labor								Prof Judgement		\$1	\$175	\$2 804	\$0			\$2 980	\$2 980
Construction Management	10% of direct materials equipment, & labor								Prof Judgement		\$2	\$350	\$5 608	\$0			\$5 960	\$5 960
Project Management	10% of direct materials equipment, & labor + ED&I								EG&G Cost Est.		\$2	\$403	\$6 450	\$0			\$6 854	\$6 854
Overhead Profit & Bond	25 3% of direct materials equipment, & labor								Facil Eng 009		\$5	\$886	\$14 189	\$0			\$15 080	\$15 080
Subcontractor Fee	10% of subcontractor costs								Facil Eng 009		\$0	\$0	\$0	\$115 000			\$115 000	\$115 000
Subtotal Indirect Capital Costs														\$292	\$2,338	\$43 072	\$115 000	\$160 702
Contingency	30% of direct and indirect capital costs								Facil Eng 009		\$93	\$1 751	\$29 747	\$379,500			\$411 092	\$411 092
Total Capital Costs														\$405	\$7,589	\$128,903	\$1,644,500	\$1 781,397

Annual O&M Direct Costs																		
Groundwater Treatment	Building 891 Water Treatment System	1	yr				\$249,600 00			\$0		(2)		\$0	\$0	\$0	\$249 600	\$249 600
Subtotal O&M Direct Costs																	\$249 600	\$249 600
Annual O&M Indirect Costs																		
Misc Labor & Materials	10% f direct labor & \$1 50 m material cost for each direct labor hour									\$0		Facil Eng 009		\$0	\$0	\$0	\$0	\$0
Project Management	10% of direct materials equipment, & labor costs									\$0		EG&G Cost Est.		\$0	\$0	\$0	\$0	\$0
Overhead Profit & Bond	25 3% of direct materials equipment, & labor costs									\$0		Facil Eng 009		\$0	\$0	\$0	\$0	\$0
Subcontractor Fee	10% of subcontractor costs									\$0		Facil Eng 009		\$0	\$0	\$0	\$24 960	\$24 960
Subtotal O&M Indirect Costs																	\$24 960	\$24 960

Activity	Resource Description	Qty	Unit	Bare Costs Per Unit				Bare Costs				Total Costs
				Mat'l	Equip.	Labor	Sub-contract	Mat'l	Equip.	Labor	Sub-contract	
Contingency	30% of total direct and indirect O&M costs							\$0	\$0	\$0	\$0	\$82,368
Total Annual O&M Cost								\$0	\$0	\$0	\$0	\$356,928
Total O&M Costs (expenditure occurs in years 11 @ 5% discount rate)								\$0	\$0	\$0	\$0	\$3,113,831

Annual Post Closure Direct Costs												
Semiannual Sampling	Collect Groundwater Samples	12	ea				\$1,500.00					\$18,000
Analytical Work	Sample Analysis for VOC & Inorganics	14	ea				\$4,100.00					\$57,400
Subtotal Post Closure Direct Costs												\$75,400
Annual Post Closure Indirect Costs												
Project Management	10% of post closure direct materials, equipment, & labor costs											\$0
Subcontractor Fee	10% of post closure subcontractor costs											\$0
Subtotal Post Closure Indirect Costs												\$0
Contingency	30% of total post closure direct and indirect costs											\$24,882
Total Annual Post Closure Costs												\$107,822
Total Post Closure Costs (13 years at 5% discount rate)												\$1,128,656

Total Cost Of Alternative				\$405	\$7,589	\$128,983	\$5,878,187	\$6,015,085
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- (1) Cost includes apor treatment and confirmatory samples
(2) Letter from Kim Ruger Group 1 Closures Building 080 to Lake Houk Group 1 Closures Building 080 December 21 1994

Table A-6 Alternative 5 Soil Excavation With Groundwater Pumping

Activity	Resource Description	Qty	Unit	Base Costs Per Unit				Source	Base Costs			Total Costs
				Mat 1	Equip	Labor	Sub-contract		Mat 1	Equip	Labor	
Direct Capital Costs												
Construct Staging Area	Towed Sheepsfoot Base Course	404	CY		\$0.70	\$0.20		Means Ref	\$0	\$283	\$81	\$364
	Reinforced Concrete Slab 6 Thick	1003	SY	\$2.12	\$0.29	\$0.22		Means Ref	\$2,126	\$291	\$221	\$2,638
	Submersible Sump Pump 5 gpm	104	CY	\$88.28	\$9.09	\$72.52		Means Ref	\$9,181	\$945	\$7,542	\$17,669
	2 PVC Piping (including fittings)	2	ea		\$300.00			Vendor Quote	\$0	\$600	\$0	\$600
		200	lf	\$1.44		\$2.04		Means Ref	\$288	\$0	\$408	\$696
Scrape Top Soil & Stockpile	Towed Scraper	376	CY		\$3.45	\$0.81		Means Ref	\$0	\$1,297	\$305	\$1,602
Dust Control	Water Truck 5 000 gal capacity	1 440	hr		\$21.32	\$25.00		Means Ref	\$0	\$30,701	\$36,000	\$66,701
Excavate Soil Haul to Staging Area	Dozer	19 692	CY		\$2.91	\$0.64		Means Ref	\$0	\$57,304	\$12,603	\$69,907
	Backhoe	985	CY		\$0.98	\$0.37		Means Ref	\$0	\$965	\$364	\$1,330
	Front End Loader	18,707	CY		\$0.66	\$0.35		Means Ref	\$0	\$12,347	\$6,547	\$18,894
	Dump Trailer	19 692	CY		\$1.15	\$0.46		Means Ref	\$0	\$22,646	\$9,058	\$31,704
		2	ea		\$400.00			Vendor Quote	\$0	\$800	\$0	\$800
Dewatering	2.5 PVC Pipe (includes fittings)	200	lf	\$1.70		\$2.19		Means Ref	\$340	\$0	\$438	\$778
	Corrugated Metal Pipe	12	lf	\$4.15		\$1.40		Means Ref	\$50	\$17	\$0	\$67
	Pea Gravel	30	CY	\$17.55				Means Ref	\$527	\$0	\$0	\$527
Rad Screening of Soil	Health & Safety Specialist	1 440	hr			\$65.00		EG&G Rad Eng	\$0	\$0	\$93,600	\$93,600
	Monitoring Equipment Maintenance	180	hr			\$55.00		EG&G Rad Eng	\$0	\$0	\$9,900	\$9,900
Treatment of Excavated Soils	Thermal Desorption Unit	19 692	CY				\$75.00	Vendor Quote	\$0	\$0	\$0	\$1,476,900
	Thermal Desorption Unit Mobilization	1	la				\$4,000.00	Vendor Quote	\$0	\$0	\$0	\$4,000
	Thermal Desorption Unit Demobilization	1	la				\$1,500.00	Vendor Quote	\$0	\$0	\$0	\$1,500
	Wheel Mounted Front End Loader	39,384	CY		\$0.66	\$0.35		Means Ref	\$0	\$25,993	\$13,784	\$39,778
Transportation/Disposal of Soil	Transportation to Disposal Facility (< 50 mi)	19 692	CY				\$33.00	Vendor Quote	\$0	\$0	\$0	\$1,043,676
	Disposal at Licensed Facility	19 692	CY				\$123.00	Vendor Quote	\$0	\$0	\$0	\$2,422,116
	Soil Samples	1 641	ea				\$250.00	Prof Judgement	\$0	\$0	\$0	\$410,250
Backfill Excavation	Pit Run Fill/Gravel 5 mi haul	19 692	CY	\$3.57	\$4.86	\$1.83		Means Ref	\$70,300	\$95,703	\$36,036	\$202,040
	Towed Sheepsfoot, 12 lifts	19 692	CY		\$0.35	\$0.09		Means Ref	\$0	\$6,892	\$1,772	\$8,664
	Revegetation	3 388	SY	\$0.22	\$0.06	\$0.06		Means Ref	\$745	\$203	\$203	\$1,152
Drill Monitoring Wells	Drill & Case 4 wells 6 diam & 20 depth	4	ea				\$10 000.00	Prof Judgement	\$0	\$0	\$0	\$40,000
Additional Field Personnel	Sr Geologist	110	hrs			\$75.00		Prof Judgement	\$0	\$0	\$8,250	\$8,250
	Surveyor	100	hrs			\$50.00		Prof Judgement	\$0	\$0	\$5,000	\$5,000
Confirmatory Sampling												
	Soil Samples From Excavation Site	25	ea				\$250.00	Prof Judgement	\$0	\$0	\$0	\$6,250
Subtotal Direct Capital Costs												
Indirect Capital Costs												
15% of direct materials, equipment, & labor												
10% of direct labor & \$1.50 m materials cost for each direct labor hour												
5% of direct materials, equipment, & labor												
Subtotal Indirect Capital Costs												
Total Project Costs												
Engineering Design & Inspection												
Miscellaneous Labor & Materials												
Permits												

Activity	Resource Description	Qty	Unit	Base Costs Per Unit					Base Costs					Total Costs
				Mat	Equip	Labor	Sub-contract		Mat	Equip	Labor	Sub-contract		
Construction Management	10% f direct material equipment, & labor													
Project Management	10% f direct materials equipment, & labor + ED&I													
Overhead Profit & Bond	25.3% f direct materials equipment, & labor													
Subcontractor Fee	10% f subcontractor costs													
Subtotal Indirect Capital Costs														
Contingency	30% of direct and indirect capital costs													
Total Capital Costs														

Annual O&M Direct Costs	Building 891 Water Treatment System	1	yr											
Subtotal O&M Direct Costs														
Annual O&M Indirect Costs														
Misc. Labor & Materials	10% of direct labor & \$1.50 m material cost for each direct labor hour													
Project Management	10% of direct materials equipment, & labor costs													
Overhead Profit & Bond	25.3% of direct materials, equipment, & labor costs													
Subcontractor Fee	10% of subcontractor costs													
Subtotal O&M Indirect Costs														
Contingency	30% of total direct and indirect O&M costs													
Total Annual O&M Cost														
Total O&M Costs (expenditure occurs in years 11 @ 5% discount rate)														

Annual Post Closure Direct Costs	Collect Groundwater Samples	12	ea											
Groundwater Monitoring	Seasonal Groundwater Sampling	14	ea											
Revegetation	10% of Excavated Area/yr	290	SY	\$0.22	\$0.06	\$0.06								
Subtotal Post Closure Direct Costs														
Annual Post Closure Indirect Costs														
Project Management	10% of post closure direct materials equipment, & labor costs													
Subcontractor Fee	10% of post closure subcontractor costs													
Subtotal Post Closure Indirect Costs														
Contingency	30% of total post closure direct and indirect costs													
Total Annual Post Closure Costs														
Total Post Closure Costs (13 years @ 5% discount rate)														

Total Cost Of Alternative														
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(1) Letter from Kim Rager Group 1 Closures Building 080 to Zeke Houk, Group 1 Closures Building 080 December 21 1994

APPENDIX B TABLE OF CONTENTS

B 1 0 INTRODUCTION	1
B 2 0 HYDROGEOLOGICAL CONCEPTUAL MODEL	2
B 3 0 MODEL FRAMEWORK	5
B 4 0 CALIBRATION	10
B 5 0 RESULTS	16
B 6 0 SENSITIVITY	18
B 7 0 UNCERTAINTY	21
B 8 0 PREDICTIONS	22
B 8 1 No Action Scenario	22
B 8 2 Institutional Controls With the French Drain Scenario	23
B 8 3 Remediation Scenario	23
B 9 0 SUMMARY	24
B 10 0 REFERENCES	27

LIST OF TABLES

B 1a Media Specific Hydraulic Parameters Used in all Contaminant Simulations	28
B 1b Contaminant Specific Modeling Parameters	29
B 2a Simulated and Observed Hydraulic Gradients	30
B 2b Simulated and Observed Hydraulic Gradients	31
B 2c Simulated and Observed Hydraulic Gradients	32
B 3 Parameters Analyzed in Sensitivity Analysis	33
B 4 Model Assumptions and Uncertainty Factors	34

ACRONYMS

CCl ₄	carbon tetrachloride
CMS/FS	Corrective Measures Study/Feasibility Study
COC	contaminant of concern
DCE	dichloroethene
DNAPL	dense non aqueous phase liquid
DOE	U S Department of Energy
IHSS	Individual Hazardous Substance Site
OU 1	Operable Unit 1
PCE	perchloroethene (or tetrachloroethene)
RFI/RI	RCRA Facility Investigation/Remedial Investigation
TCA	trichloroethane
TCE	trichloroethene
VOC	volatile organic compound

B 1 0 INTRODUCTION

Appendix B presents the results of a subsurface solute transport model of the OU 1 site. The purpose of the model is to provide a basis for residual risk calculations and design calculations for the feasibility study. In this appendix the following topics are discussed: the hydrogeological conceptual model of the site, the framework of the corresponding numerical model, the results and predictions of the model, and a qualitative discussion of model uncertainty. Tables and figures are included in the back of this appendix after the references.

B 2 0 HYDROGEOLOGICAL CONCEPTUAL MODEL

The OU 1 conceptual model describes the primary processes that control the movement of solutes in the subsurface. Such processes include groundwater flow rates and directions, solute release rates and timing, recharge and discharge rates, dispersion, degradation rates, and adsorption.

The groundwater flow system beneath the hillside at OU 1 is described in detail in the Phase III RFI/RI (DOE 1994). The following description is limited to features at IHSS 119.1 that are incorporated into the flow and transport model of the site. IHSS 119.1 is where most of the observed contamination at the site is located.

Groundwater flow beneath the hillside occurs in shallow colluvial, alluvial, and bedrock units, with most of the flow concentrated in the colluvium and alluvium (DOE 1994). Groundwater flow tends to be focussed in areas of thick colluvium which generally correspond to topographic features. The thick colluvium is probably produced by deep bedrock weathering in the area. The weathering is assumed to be caused by oxygenated water infiltrating the bedrock located beneath streambeds.

Site data from Volume IV, Appendix A of the Phase III RFI/RI (DOE 1994) supports the theory that thick colluvium is found beneath streambeds. The vertical section of the French Drain from Station 16+00 to 16+50 shows a thick band of colluvium beneath the drainage and the shear plane as conforming with the bedrock channel. This shear plane may correspond to the depth of bedrock weathering. Therefore, there may be a relationship between the depth of weathering and soil volume affected by slope instability.

One hydrologic drainage that extends upslope into IHSS 119.1, illustrated in Figures 3.23 and 3.24 of the Phase III RFI/RI (DOE 1994), is where most of the groundwater in the vicinity of IHSS 119.1 flows. Site data indicate that it has a thick band of colluvium. Therefore, it is assumed that groundwater is generally channelized along hydrologic drainages.

Recharge and discharge vary in the short term at the site primarily because of the low groundwater volume and its large dependence on rainfall events and infiltration. However, an average rate of recharge or discharge can be calculated from infiltration equations and long term precipitation averages from site data or records from the National Oceanic and Atmospheric Administration. No site specific calculations or field measurements of recharge or discharge are available.

Recharge to groundwater is assumed to occur from interflow and bedrock flow from the Rocky Flats alluvium and is significantly affected by the low permeability of the colluvium and alluvium at the site. Recharge is decreased during arid conditions and high rainfall events because of the lowered infiltration capacity and permeability of the soil. Similarly, it is increased during spring and fall when the soil has a greater infiltration capacity.

Groundwater discharge is assumed to occur due to the low permeability and moisture content of the soil and the low flow conditions caused by the arid climate at the site. It occurs as evapotranspiration and flow into Woman Creek (Fedors et al 1993a and 1993b). Flow into Woman Creek is indicated by calculated hydraulic gradients of the site and the theory that the groundwater follows topographic features.

The primary source of contamination is assumed to be located in the subsurface soil at IHSS 119.1. During the 1960s and 1970s, drums containing volatile organic compounds (VOCs) were stored at IHSS 119.1 (DOE 1994). Probable releases from the drums may have resulted in a residual DNAPL in the subsurface soil. The residual DNAPL phase has not been directly observed but is indicated by high concentrations of VOCs in the areas near Well 0487, Well 4387, Well 4787, and Well 5587. The drums are assumed to have started leaking their contents into the soil in 1970 although it is not specifically known at this time. The primary groundwater release mechanism is assumed to be dissolution of residual DNAPL assisted by infiltration.

The transport of contaminants in groundwater is controlled by groundwater direction and flowrate. Other processes that affect contaminant fate and transport are hydrodynamic.

dispersion degradation and adsorption Hydrodynamic dispersion is simulated using dispersivity groundwater velocity and molecular diffusion Degradation rates and sorption properties for VOCs are discussed and reported the Phase III RFI/RI (DOE 1994)

B 3 0 MODEL FRAMEWORK

The computer simulation code TARGET_2DU (Dames & Moore 1985) was used to simulate contaminant transport in the subsurface. TARGET_2DU is a vertically oriented two dimensional finite difference model that can simulate variably saturated conditions. For the purposes of this CMS/FS TARGET_2DU was modified to simulate a source with a constant concentration.

Because the model is two dimensional it cannot simulate dispersion (spreading) transverse (perpendicular) to the model section. Therefore the modeled dispersion in the plane of the model will be greater than the actual dispersion. Consequently the model is conservative and will overestimate dispersion because it does not account for spreading of contaminants in transverse to the model plane.

The model grid as shown in Figure B 1 is 296 horizontal cells by 170 vertical cells. It has approximately 25 000 active cells. The grid was designed to capture details of the bedrock/colluvium interface and topography to accurately simulate the vadose zone and to minimize errors caused by numerical dispersion. The location of the section of the model is shown in Figures B 2 and B 3 and corresponds to the trough of thicker colluvium at IHSS 119 1.

Two criteria are used to ensure minimal numerical dispersion: the Peclet number and the Courant number. The grid Peclet number is the ratio of grid spacing (length of a cell side) to dispersivity. To minimize numerical dispersion the Peclet number generally should be less than or equal to one. For this model dispersivity is much larger than cell lengths so the Peclet number is much smaller than one. The grid Courant number is the ratio of time step interval to groundwater travel time across a cell. Similar to the Peclet number the Courant number generally should be less than or equal to one. Because of low gradients and hydraulic conductivities and moderate sorption the Courant number for this model is much smaller than one.

The distribution of boundary conditions and soil types are shown in Figures B-4 and B 5. Soil properties, degradation rates, and adsorption distribution coefficients for the COCs are listed in Tables B 1a and B 1b. The degradation rates used in the model were the maximum values listed in the Phase III RFI/RI (DOE 1994) and they reflect the slowest anticipated degradation rates at the site.

Figures B 7 through B 12 show the relationship between relative saturation, relative hydraulic conductivity, and pressure head as specified in the model. Calculated relative hydraulic conductivity refers to values calculated by Fedors et al (1993b) using Van Genuchten's equations relating pressure head, relative saturation, and relative hydraulic conductivity (Van Genuchten 1980). The curve for colluvium is based on site data (Fedors et al 1993b) as indicated in the figure. The curves for bedrock and alluvium in the Woman Creek drainage are based on material #1 and material #2, respectively, in Table 3.1 of Fedors et al 1993a.

Each soil type is assumed to be homogeneous within the type and heterogeneous between types. Therefore, heterogeneity in the model is limited to the colluvium, alluvium, and bedrock layers. These lithologies have been identified and defined during the site characterization activities. Fractures in the colluvium resulting from slope instability are assumed to be healed, so that fractures do not provide preferential flowpaths. It is assumed that most instabilities do not occur unless initiated by human activities and that, if active slumping probably occurs at an imperceptibly slow rate. If these observations are correct, then discontinuities (fractures) caused by mass movements would heal quickly in the easily deformed colluvium. This is supported by the lack of distinct features typically associated with slumping, i.e., discontinuities such as tension cracks at the upslope end of a slump. The lack of such features is assumed to be due to the slow rate of movement and to the characteristic deformability of colluvium.

For the French Drain, a constant head cell of 5876.2 ft (1791.1 m) was set at the bottom of the drain to simulate flow to the drain, as shown in Figure B 5. The extraction well was simulated in the same manner, but with an elevation of 5910.2 ft (1801.4 m). These elevations were set slightly above the interface between bedrock and colluvium material based on the assumption

that the French Drain and extraction well could not draw groundwater down to the interface. If this happened, the saturated thickness would approach zero and the flow would decrease to zero. Simulations using the French Drain and extraction well are discussed in detail in following sections.

The bottom of the model was selected to be somewhat lower than the elevation of Woman Creek, which is considered to be the ultimate discharge point for groundwater at the site. The French Drain is currently the assumed groundwater discharge point but was not included in the model to decrease the complexity of the site. Because flow rates in the bedrock are much lower than those in the colluvium, the model is not very sensitive to the location of the colluvium bedrock boundary.

The primary contaminant source was simulated using a constant concentration boundary condition based on the assumption that a slow dissolution of residual DNAPL is the source of groundwater contamination. The source cell shown in Figure B 5 is located at the interface between bedrock and colluvium material in the model where elevated concentrations of contaminants in groundwater have been observed. Because the soil is fine grained and has low permeability, the likelihood is small that there is a large, continuous, and mobile DNAPL present. In support of this conclusion, the following hypothetical cases are considered:

- Hypothetical Case 1 Large spill of DNAPL caused observed contamination. Spill would spread over a large area because of the low permeability soil. DNAPL would penetrate only shallow soil due to spreading and reduced DNAPL source hydraulic head. Large dissolved concentrations would be observed over a wide area relative to the spill location.
- Hypothetical Case 2 Small episodic spills of DNAPL caused the observed contamination. DNAPL would penetrate further into low permeability soil than Case 1. However, penetration would be limited due to the source's low hydraulic head. DNAPL would rapidly achieve residual saturation as source head is dissipated. Large dissolved concentrations would be observed over a small area relative to the spill location.

The descriptions in the hypothetical cases above are based on information presented by Cherry.

et al 1990 Case 2 is consistent with the large VOC concentrations observed in a limited area at IHSS 119 1 It is also consistent with how the site was used historically i e as a drum storage area rather than for activities in which solvents were actively used and spilled at the site Based on consideration of these two cases and on the measured concentrations at the hillside the most reasonable situation is that the source in the subsurface is an immobile residual DNAPL

Because soil instabilities have been documented at the OU 1 area (DOE 1994) the colluvium and bedrock involved in the movements is potentially fractured To flow into a fracture or pore DNAPL must overcome the displacement pressure required to displace water (Cherry et al 1990) which is the wetting phase at the site Therefore DNAPLs would be less susceptible to flow in fractures where water is present In addition as the fracture aperture decreases, more DNAPL head is required for flow to occur into the fracture The same principles apply to fine grained soil as well DNAPL if present at the site would be found in larger fractures and more coarse grained soil (Cherry et al 1990)

For significant DNAPL movement into fractures the fractures must be interconnected or in direct connection with a large volume of DNAPL Fractures in claystone and siltstone are typically of small extent few in number and poorly connected Therefore it is not likely that significant DNAPL movement into fractured bedrock has occurred at IHSS 119 1

Figure 5 10 of the Phase III RFI/RI (DOE 1994) shows the probable situation at OU 1 with regard to DNAPL with the exception of (1) a pool of DNAPL in the colluvium and (2) movement into bedrock fractures The first exception based on Case 2, is that the spill must have been small and episodic which would not have resulted in a large mobile saturated pool The second exception based on the previous discussion regarding DNAPL flow into fractures and pores is that the DNAPL volume would have to be large to cause such a movement otherwise the driving DNAPL head would not have overcome the displacement pressure In addition the fractures would have to have been well interconnected

Based in part on the oscillatory behavior of observed concentrations in wells at the site the source is assumed to release solutes on a periodic basis i.e. release occurs at the solubility limit for a DNAPL for six months of a year and does not occur the remaining six months. Therefore the source switches between an active and an inactive state. This concept is also consistent with the probable configuration of the residual DNAPL. Much of the DNAPL may be above the saturated zone during dry conditions so that dissolution will not occur and there is no migration to groundwater. As wetter conditions prevail however, dissolution of the residual DNAPL would occur as it contacts groundwater.

B 4 0 CALIBRATION

The model was calibrated using steady state flow for the time prior to the installation of the French Drain and transient flow from the time of the French Drain installation to the present. The flow calibration is assumed to be conservative because the model always assumes flow occurs whereas there are many areas and times of either no flow or low flow due to the arid climate (DOE 1994).

The calibration procedure was qualitative due to a limited number of wells for comparison. This is a commonly accepted method of calibration particularly when observation data is scarce. Statistical measures and automated techniques require a moderate to extensive data set to produce meaningful and useful results. For this study several calibration targets were used to enhance model reliability such as water levels, calculated gradients and COC concentrations. Parameter values used in the model lie within measured or probable ranges.

The primary goal in calibrating the flow portion of the model was to match the observed and calculated hydraulic gradients between Wells 4387 to 0487, 0487 to 4787 and 4787 to 5587 to determine if the model accurately simulates advective transport rates. Tables B 2a through B 2c which can be used for comparative purposes lists observed and simulated gradients for these well pairs. As indicated in the tables between Well 4387 and Well 0487 and between Well 0487 and Well 4787 the simulated hydraulic gradient is between the minimum and maximum calculated gradients based on site data. Therefore, downgradient of the French Drain and between the source and Well 4787 the model accurately simulates average advective transport times. Between Well 4787 and Well 5587, the simulated hydraulic gradient is smaller than the minimum calculated gradient based on site data.

Between Well 4787 and Well 5587, the model simulates lower advective transport rates than the calculated rates that were based on site data. However since the model overestimates the water level in Well 5587 the simulated gradient between Well 5587 and Woman Creek is likely higher than actual. Thus modeled COCs may be transported more rapidly than actual COCs between

Well 5587 and Woman Creek This would tend to offset the slower transport rate simulated between Well 4787 and Well 5587

One parameter that was the focus of the calibration is the areal discharge rate To achieve calibration a net areal discharge of 2.96 in/yr from the water table was used A net recharge to groundwater yielded a simulated potentiometric surface aboveground which is not observed at the site The other focus of the flow calibration was determining the hydraulic conductivity of the various soil specified in the model The selected values lie within measured or probable ranges

A secondary goal of the flow calibration was to match simulated and observed water levels Figures B-13 through B-16 show simulated and observed hydrographs for Wells 0487 4387 4787 and 5587 respectively Although the model generally overestimates water levels the overall hydraulic gradients and therefore Darcian transport velocities are comparable to those observed at the site

The flow mass balance provides a measure of how well the model is calibrated Discrepancies in the mass balance generally should be smaller than 5% especially for groundwater flow, otherwise errors in the flow domain may adversely affect subsequent transport simulations As illustrated in Figure B 17 the percent discrepancy between simulated inflows and outflows ranges from about 17% to 4% Large changes in mass error are related to changes in hydraulic conditions such as the simulation of extraction wells During these changes in hydraulic conditions different or new stresses will cause temporary and sometimes large changes in ground water flow This typically causes the mass error to change As the flow domain begins to adjust to the new change the mass error will decrease

Mass error is related to model size and complexity In general as models become larger or more complex the mass error becomes larger Larger models involve more calculations so that the net error being a sort of sum over the active model cells will tend to have a larger error For example in a model having 10 constant head cells the flows in and out of these cells

depends on the head simulated adjacent to them. Thus the flow to or from each constant head cell can vary and result in some intrinsic mass error in flow caused by the numerical approximation and implementation of the simulation code. Given the same number of closure criteria, similar models with twice as many constant head cells have generally the same or higher error than for a model with fewer constant head cells. This is due to the summation over the constant head cells. However, the larger model may converge just as well as the smaller one even though the error is larger.

A similar effect is commonly observed for models with greater complexity. A model with more variation in hydraulic conductivity, for example, will typically have greater error given similar closure criteria. This is caused by the greater complexity in the interrelationships between model cells than between boundary conditions. Even with a larger error, more complex models may be as well converged as simple models due to the complex interrelationships between cells.

Another commonly observed phenomenon is that subdomains within the model may be very well converged while other areas are moderately to poorly converged. As long as the moderately to poorly converged parts are not in areas of specific interest, then the model generally can be considered converged adequately for practical purposes. This is possible despite the appearance of poor convergence or mass balance.

The minimum acceptable error depends on the model's size and complexity, with a larger error being acceptable for larger or more complex models. The OU 1 groundwater flow and transport model is large and somewhat complex. Therefore, the mass errors depicted in Figures B 17 are considered acceptable.

Convergence of the model with regard to flow rate and direction was good, exhibiting monotonic behavior as indicated in Figure B 18. The figure shows the normalized sum of the absolute value of mass error over all active model cells for all time steps. To normalize the sum, each value was divided by the maximum absolute value of the sum so that all values range between zero and one. For transient flow calculations, the sum decreases from an initially large value for

each time step showing the monotonic convergence of the model at each time step. This results in the sawtooth pattern in Figure B 18. The initial flat part of the curve in Figure B 18 corresponds to the first part of the transient transport calculation when steady state flow is specified. Transient flow calculations start at about the 400th iteration where there is a spike in the sum.

After calibrating the steady state flow, transient transport simulations were done for each contaminant. The same trial and error technique was used in calibrating the transport model. The primary parameter changed during the transport calibration was the time that the source became active and inactive. Simulation of a continuous, constant concentration source resulted in excessively and unrealistically large concentrations at all observation points. Priority in calibrating to Well 0487 was selected because it is closer than Well 4387 to points of demonstration which are located immediately downgradient of the French Drain and prior to discharge into Woman Creek. Also, simulated concentrations that exceeded observed concentrations were preferred in the model to make it more conservative.

Transport simulations started with the steady state flow field, continued for 20 years, then incorporated the French Drain and extraction well as shown in Figure B 6. Each transport simulation was calibrated in a manner similar to that used for the flow calibration. Figures B 21 through B 30 show breakthrough curves for each of the COCs, with observed concentrations for comparison. Three key components of the transport calibration are shown in these graphs:

- COC concentrations are always overpredicted by the model. The implications of this are: (1) estimated exposure concentrations are conservative because they bound observed concentrations; (2) alternate source locations and conditions (such as a source located somewhere outside the plane of the model or a source with a different release mechanism such as diffusion from fractures in bedrock) are indirectly accounted for by the model; a different source is unlikely to result in higher predicted concentrations; (3) spreading of a source caused by degradation and subsequent generation of a COC along a flowpath is also accounted for by the model because the estimated concentrations are much higher than actually observed; (4) predictive simulations overestimate COC concentrations because they are based on the same concepts as the calibrated model, and (5) if the model was more realistic, the simulated concentrations would be smaller and more consistent with observed data.

which would translate into smaller concentrations under the predictive simulations

- The model simulates relatively well the oscillatory behavior observed in actual concentrations. This supports the concept that the source periodically releases solutes and that the timing is related to seasonal variations in climatic conditions.
- The model accurately predicts the effects of the French Drain and the extraction well. The rise in simulated 1,1-DCE and 1,1,1-TCA concentrations in Figures B-27 and B-25 respectively that occur around 1992 is caused by simulating the operation of the French Drain which started construction in November 1991 and finished in April 1992. The rise in concentrations is caused by the increased hydraulic gradient resulting from the installation and operation of the French Drain which pulls groundwater more rapidly towards Well 0487. The simulated concentrations begin decreasing around 1993 when the extraction well started operating. The gradients are reduced when the extraction well is simulated because it pulls groundwater away from Well 0487. The observed concentrations vary in the same manner. The similarity between the model and observed variations in concentrations leads to the conclusion that the observed variations are caused by the installation and operation of the French Drain and extraction well. That the model simulates this behavior underscores the conclusion that the model is an accurate and adequate representation of site conditions. The spiking effect caused by the French Drain is observed in all COCs.

The last component of the modeling addresses the issue of a mobile DNAPL. Because the model provides a simple and plausible explanation for observed spikes in VOC concentrations and the existing site data do not suggest its presence, it is assumed that one does not exist.

As with flow, the COC mass balance provides a measure of how well the model is converged. Discrepancies in the mass balance should be smaller than 10%. The percent mass error for TCE depicted in Figure B-19 is calculated by using the ratio of the mass error to the total solute mass in storage. The change in relative error at about 1992 is caused by simulating the French Drain and in 1993 by the extraction well. Percent error ranges from nearly 0 to 5.5% which is acceptable for the model.

The transport convergence is moderately good, exhibiting monotonic behavior as indicated in Figure B-20. The plotted sum value is calculated the same as the sum value for flow. The spikes at larger iterations correspond to changes in boundary conditions, i.e., the simulation of

the French Drain and extraction well. This behavior mimics the observed behavior for mass error and is caused by the same effects. Some oscillatory behavior is observed, however, because the transport calculations rapidly converge at each time step. This is typical for transport calculations. The oscillatory behavior is caused largely by the size and complex nature of the model.

B 5 0 RESULTS

This section presents a discussion of the results of the calibrated flow and transport model (often referred to as the baseline calibrated model). From the calibrated steady state flow simulation illustrated in Figure B 31, groundwater flow rates and directions can be obtained. Figures B 32 through B 34 show the effects of the French Drain and extraction well on groundwater flow. The French Drain and extraction well both draw down the water table resulting in drawdown cones that extend upgradient into IHSS 119 1. As expected, the drawdown cones are asymmetrical due to the slope of the water table. The effect of the French Drain and extraction well on COC transport was discussed in Section B 4 0.

A water budget accounts for the flow into and out of the model domain. Steady state flow into the model domain is simulated to be about 2.09 ft³/day (0.059 m³/day) mostly from the Rocky Flats Alluvium. Discharge from the model occurs as evapotranspiration and flow to Woman Creek. Evapotranspiration is estimated to be 0.59 ft³/day (0.017 m³/day) and flow to Woman Creek is estimated at 1.76 ft³/day per foot of creek bed (0.1635 m³/day per m). Observed flow in Woman Creek is highly variable (DOE 1994); however, the average for May 1990 and September 1990 is about 13 ft³/day (0.368 m³/day) with a range of 2.16 ft³/day (0.061 m³/day) to 23.76 ft³/day (0.673 m³/day). Because the model represents average long term conditions and the observations are highly variable, the modeled flow is considered to be comparable to the observed conditions.

Under transient conditions, simulated flow into the French Drain is about 0.0144 ft³/day (4.078 x 10⁻⁴ m³/day) per foot of drain and flow into the extraction well is about 0.173 ft³/day (4.90 x 10⁻³ m³/day). Measured flow into the French Drain represents flow from most of the site, making it difficult to compare the model and observed measurements because of the large amount of flow that originates from the Building 881 footer drain. However, measured flow into the drain is about 673.75 ft³/day (19.08 m³/day). Assuming that the distance over which the model represents groundwater flow as 1,435 ft (437.4 m), then the net simulated flow into the drain is 206.86 ft³/day (5.86 m³/day). For the extraction well, measured flows average

0 225 ft³/day (6.37×10^3 m³/day) which are very similar to that simulated by the model

Results of transport simulations for PCE are discussed in detail in the following paragraphs. Results of other COC simulations will not be discussed because the compounds tend to behave similarly.

The modeled PCE plume after 22 (pre French Drain), 23, 26, and 28 years is shown in Figures B 35 through B 38. The plume moves downgradient slowly at a rate of about 0.061 ft/day (0.0186 m/day) and appears to penetrate a small distance into the bedrock. The majority of movement is in the colluvium due to higher groundwater flow rates. Some migration in the vadose zone is also simulated corresponding to dispersion in soil moisture.

After 24 years, the French Drain and extraction well have a significant effect on the plume as shown by Figures B 37 and B 38 and discussed in Section B 4.0 regarding calibration. The extraction well pulls the plume back toward IHSS 119.1, and the French Drain captures the plume trapped between it and the extraction well.

B 6 0 SENSITIVITY

Sensitivity analyses are used to assess the response of a model to changes in specific parameters. Parameters that exhibit a large sensitivity or response are those for which small changes result in widely variable response. Values for sensitive parameters in a calibrated model are generally considered to be more certain because there is only a small range in the parameter's values over which model calibration can be achieved.

The method used in this study involved changing a parameter value in the calibrated flow and transport model, re-executing the model, and recording the response. The variation in PCE concentration at the French Drain demonstration point was used to assess model response. The parameters in the sensitivity analysis were selected based on their probable sensitivity. The selected parameters were porosity, decay rates, adsorption, and hydraulic conductivity because each has the potential to directly affect transport rates and simulated concentrations.

Other parameters were not selected because they are less likely to affect simulated concentrations. For example, the density difference at the source for PCE is calculated to be 0.015%, which is far below the generally accepted criteria of 1% (Mackay et al 1985) used to assess the importance of density coupled flow and transport. The density difference is calculated by assuming that 150 mg/L of a compound meant that the density ratio of the compound to water was 150 / 1,000,000. Therefore, the density difference is 0.015%.

Table B 3 lists the changes in parameters that were made to assess model sensitivity. Figures B 39 through B-46 illustrate the results of each simulation and the percent difference in concentration relative to the baseline calibrated model. Each parameter is discussed in the following paragraphs.

The results of the sensitivity analysis for adsorption are shown in Figures B 39 and B-40. The first figure shows the results of the two sensitivity cases and the baseline calibrated results for comparison. The second figure shows the percent difference in PCE concentration relative to

the baseline calibrated model. As time progresses, the sensitivity with respect to adsorption decreases. In all cases, the shapes of the curves exhibit an exponential form, which is due to the inclusion of decay in the analyses.

Changes in adsorption cause a constant shift in a breakthrough curve. Such a shift will result in a bell shaped difference curve, and when overprinted with decay, the bell shaped curve is also shifted in the vertical direction. This explains the form of the curves for adsorption. Greater adsorption results in smaller simulated concentrations. Smaller adsorption results in larger simulated concentrations. The sensitivity of adsorption decreases with time as decay begins to have a significant effect on COC concentrations. In both cases, the concentrations approach but never equal the baseline concentrations due to the overriding effect of the decay rates.

In the decay sensitivity analysis, decay was not simulated so the sensitivity increases with time as shown in Figures B-41 and B-42. If decay had been set to a value smaller than that in the baseline model, the opposite sensitivity would be observed. The smallest differences occur for times less than 10 half lives. This is because smaller amounts of decay are simulated at shorter times.

The porosity sensitivity, as shown in Figures B-43 and B-44, is similar in form to adsorption. Changes in porosity result in slower or more rapid transport time and when compounded with decay, the breakthrough curve is shifted laterally and vertically. Meaningful percent differences do not start until about 1973, when noticeable breakthrough begins. Concentrations at the onset of the model represent extremely small values of concentration which may be due to numerical dispersion. The actual concentration is zero, but the modeled results, and hence the difference curve, are not zero at the onset. This phenomenon affects most of the sensitivity results at the onset of the model.

Changes in hydraulic conductivity affect transport rate and dispersion (Figures B-45 and B-46). Conceptually, two breakthrough curves for the same model with only differing hydraulic

conductivity should result in similar breakthrough curves with varying vertical and horizontal offsets. For the case in which hydraulic conductivity was decreased the response was smaller because the change in conductivity was smaller relative to the baseline calibrated value. Hydraulic conductivity is consistently the most sensitive parameter in the model.

The order of greatest to least sensitivity of the parameters studied is

$K_{xx} \gg \gg \text{Decay} > \text{Porosity and Adsorption}$

with hydraulic conductivity (K_{xx}) much more sensitive than the other parameters. The results of the sensitivity analysis verify the theoretical analysis of the governing equations. The analysis indicates that small changes in parameters result in large differences in concentration. The model is considered robust because only a small range of values will give appropriate calibration.

B 7 0 UNCERTAINTY

This section is a qualitative discussion of uncertainties associated with the model. In general, uncertainties can be divided into two types. The first type results from an incomplete knowledge of the system or processes. A real system can often be too complex or lack the necessary information to be completely understood or modeled without making simplifying assumptions. Parts of the system or processes may also be omitted because they are thought to be less important than others. The second type of uncertainty relates to the values assigned to input parameters used to describe the system or processes. In reality, input parameters are not single values but vary over a range of possible values.

Table B-4 lists specific model assumptions or uncertainty factors that could contribute to variations in model predictions. The second column of the table gives the source of the uncertainty. Not simulated means a particular transport or transformation process was not considered in the modeling. Measurement Error indicates that there could be some unknown or unmeasured variability or heterogeneity in the corresponding property. Not Measured indicates that the parameter has not been measured under site specific conditions either in the field or in the laboratory. In the third column, Incorrect Flows indicates that a different flow could result by a corresponding change in the parameter. The fourth column lists the relative degree of uncertainty.

The combination of parameters used in the model is not considered to be unique. Other combinations of the parameters may yield a similar result. However, the parameter values used generally lie within observed and accepted ranges, and therefore the model is considered representative of site conditions.

B 8 0 PREDICTIONS

For predictions in which the source is not remediated the source is assumed to be large enough to provide an infinite supply of groundwater contamination. In such simulations the source concentration is held constant throughout the simulations. For predictive simulations in which the source is remediated the concentrations in a 200 foot area of colluvium around IHSS 119 1 are set to the appropriate water quality standard. For alternatives in which the French Drain and extraction well are removed the steady state flow conditions used for the first part of the simulations are re imposed based on the assumption that steady state flow is rapidly re established relative to the total time of simulation. For all other predictions steady state flow is assumed to exist at the beginning of the predictive part of the simulation i.e. the French Drain and extraction well are assumed to create an essentially steady state condition by the time the predictive simulation starts.

Two points of demonstration are used to show the results of the predictive simulations. The first is located on the downgradient side of the French Drain about halfway between the water table and the colluvium bedrock interface (see Figure B 38). The second point is located immediately upgradient of Woman Creek in the alluvium.

B 8 1 No Action Scenario

In Alternative 0 the French Drain and extraction well are removed but the source is not remediated. Transport simulations beginning from 1996 and continuing through 2028 were done for each of the COCs. Under this scenario the plume continues to grow with time because the source remains in place providing a constant release. Figures B-47 through B 56 show the variation of concentration with time at the French Drain and Woman Creek. At the French Drain the installation of the drain and extraction well cause a dip in concentrations. After the drain and well are removed concentrations begin to recover and increase due to a continuing source and desorption. At Woman Creek similar results are obtained however due to the longer travel distance and time the features of the curves are more subdued and the small dips

in concentration are caused by changes in the flow system such as the installation of the French Drain upgradient (in groundwater) of Woman Creek

B 8 2 Institutional Controls With the French Drain Scenario

Under Alternative 1 the French Drain and extraction well remain in operation. No remediation of the source takes place under this scenario. Transport simulations beginning from 1998 and continuing through 2028 were done for each of the COCs. Under this scenario the plume is drawn to and captured by the extraction well and French Drain. Figures B 57 through B 66 show the variation of concentration with time at the French Drain and Woman Creek. At the French Drain the installation of the drain and extraction well cause a dip in concentrations. With the drain and well in place concentrations peak for COCs with shorter half lives. Desorption provides a decreasing but undecayed source. At Woman Creek similar results are obtained with differences caused by the longer travel distance.

B 8 3 Remediation Scenarios

Under Alternatives 2, 3, 4, and 5, the French Drain and extraction well are removed and the source is remediated. Transport simulations beginning from 1998 and continuing through 2028 were done for each of the COCs. For these simulations a 200 foot strip of colluvium assumed to be remediated to the appropriate water quality standard. Under this scenario the plume that remains in place after the source is removed continues to move downgradient with time. Figures B 67 through B 76 show the variation of concentration with time at the French Drain and Woman Creek. At the French Drain the installation of the drain and extraction well cause a dip in concentrations. The curves exhibit behavior that is a combination of the other sets of alternatives i.e. concentrations that rise briefly after the drain and well are removed but rapidly decrease due to source remediation. At Woman Creek similar results are obtained with differences caused by the longer travel distance.

B 9 0 SUMMARY

A groundwater flow and contaminant transport model has been developed and calibrated for OU 1. The model was used to simulate and predict contaminant movement from IHSS 119 1 to the French Drain and Woman Creek. The results of the model are used in characterizing the residual risk associated with each of the remediation alternatives.

The model is considered to be conservative for the following reasons:

- The model is two dimensional therefore dispersion (spreading) transverse to the plane of the model is not simulated. This causes an overestimation of the COC concentrations.
- The flow calibration is conservative because the model always assumes groundwater flow occurs whereas there are many areas and times of either no flow or low flow due to the arid climate (DOE 1994).
- Concentrations are generally always overestimated by the model. The implications are: (1) estimated exposure concentrations are conservative because they bound observed concentrations; (2) alternate source locations and conditions (such as a source located somewhere outside the plane of the model or a source with a different release mechanism such as diffusion) are indirectly accounted for by the model; i.e. a different source is unlikely to result in higher predicted concentrations; (3) spreading of a source caused by degradation and subsequent generation of a VOC along a flowpath is also accounted for by the model because the estimated concentrations are much higher than actually observed; (4) predictive simulations overestimate VOC concentrations because they are based on the same concepts as the calibrated model; and (5) if the model were more realistic the simulated concentrations would be smaller and more consistent with observed data which translates into smaller concentrations under the predictive simulations.

The model is calibrated to average site conditions for flow and transport with adequate agreement between the model and observed conditions. The model indicates a good mass balance and exhibits monotonic convergence which is indicative of accurate calculations. The model is considered adequate for predictive purposes and representative of site conditions for

the following reasons

- The hydraulic gradients simulated in the model are generally within the range calculated using site data. Therefore advective transport rates are indicative of site conditions
- The model simulates relatively well the oscillatory behavior observed in actual concentrations. This supports the concept that the source periodically releases solutes and that the release is likely related to seasonal variations in climatic conditions
- The model approximates the effects of the French Drain and the extraction well with moderate accuracy. The rise in simulated DCE and TCA concentrations that occur around 1992 is caused by simulating the French Drain. The rise in concentrations is caused by the increased hydraulic gradient resulting from the installation and operation of the French Drain. The drain begins to pull groundwater towards Well 0487. The simulated concentrations and hydraulic gradient begin decreasing around 1993 when the model begins simulating the extraction well. The extraction well pulls groundwater away from Well 0487. The observed concentrations vary in the same manner. The similarity between the model and observed variations in concentrations leads to the conclusion that the observed variations are caused by the installation and operation of the French Drain and extraction well. That the model simulates this behavior underscores the conclusion that the model is an accurate and adequate representation of site conditions. The spiking effect caused by the French Drain is observed in all COCs

The last component of the modeling investigated the issue of a mobile DNAPL. Because the model provides a simple and plausible explanation for observed spikes in VOC concentrations and existing site data do not suggest the presence of a mobile DNAPL, it is assumed that one does not exist.

The order of greatest to least sensitivity of the parameters studied is

$K_{xx} > > > \text{Decay} > \text{Porosity and Adsorption}$

with hydraulic conductivity (K_{xx}) being more sensitive than the other parameters. The results of the sensitivity analysis verify the expectations from a theoretical analysis of the governing

equations The analysis indicates that small changes in parameters result in large differences in concentration The model is considered robust because only a small range of values will give appropriate calibration

Three modeling scenarios were simulated representing different alternatives Predicted results for the No Action Alternative indicate that concentrations at the French Drain and Woman Creek will increase to peak concentrations within 30 years Predicted results for the Institutional Controls with the French Drain Alternative indicate that concentrations at the French Drain and Woman Creek will decrease with time Peak concentrations occur at the time of the alternative s implementation Predicted results for the remediation alternatives indicate that concentrations at the French Drain and Woman Creek will increase slightly then decrease with time Peak concentrations occur within 30 years

B 10 0 REFERENCES

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Mackay D M Roberts P V and Cherry J A 1985 *Transport of Organic Contaminants in Groundwater* Environmental Science and Technology Volume 19 Number 5 pages 384 392

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Table B-1a
Media Specific Hydraulic Parameters Used in all Contaminant
Simulations

Hydraulic Parameter	Units	Bedrock	Colluvium	Alluvium
Horizontal hydraulic conductivity	ft/d (m/d)	0 06 (018)	0 45 (137)	6 (1 829)
Vertical hydraulic conductivity	ft/d (m/d)	0 06 (018)	0 2 (061)	3 (914)
Specific storativity	1/ft (1/m)	1E-4 (3 3E-4)	1 5E-4 (4 9E-4)	3 5E-4 (1 1E 3)
Porosity	--	0 35	0 36	0 45
Density of clean groundwater	mg/L	1 0E+6	1 0E+6	1 0E+6
Bulk density ratio	--	1 81	1 5	1 65
Molecular dispersion	ft ² /d (m ² /d)	1E-4 (9 3E-6)	1E-4 (9 3E-6)	1E-4 (9 3E-6)
Longitudinal dispersivity	ft (m)	20 (6 096)	30 (9 144)	40 (12 192)
Transverse dispersivity	ft (m)	2 (6096)	10 (3 048)	10 (3 048)
Coefficient for Sr (psi)	1/ft (1/m)	0 24 (0 79)	5 58E 2 (0 18)	3 (9 8)
Coefficient for Sr (psi)	--	1 09	1 22	2 5
Coefficient for Sr (psi)	--	-0 826	-0 18	-0 6
Residual moisture content	--	0 25	0 59	0 1
Saturated moisture content	--	0 35	0 377	0 45
Coefficient for Kr (psi)	1/ft (1/m)	0 83 (2 72)	0 0148 (0486)	3 48 (11 42)
Coefficient for Kr (psi)	--	0 41	0 44	1 93
Coefficient for Kr (psi)		3	10	3
Minimum Kr (psi)		0 1	0 1	0 1

Table B-1b
Contaminant-Specific Modeling Parameters

Contaminant	Distribution Coefficient (L/mg)	Half Life (days)	Source Concentration (mg/L)
Tetrachloroethene (PCE)	4 34E 7	730 5	150
Trichloroethene (TCE)	3 80E 7	1643 6	1100
1 1 1 Trichloroethane (TCA)	3 99E 7	546	1500
1 1 Dichloroethene (DCE)	3 08E 7	154	5500
Carbon tetrachloride (CCL ₄)	4 50E 7	365 25	757

Table B-2a
Simulated and Observed Hydraulic Gradients

Well 4387				Well 0487			
Date of Water Level ^a	Observed Water Level (ft)	Model Time ^b (days)	Simulated Water Level (ft)	Date of Water Level ^a	Observed Water Level (ft)	Model Time ^b (days)	Simulated Water Level (ft)
6/10/89	5917.3	7480.10	5920.54	06/09/89	5902.0	7480.10	5904.76
1/16/90	5916.6	7691.25	5920.54	01/16/90	5899.2	7691.25	5904.76
4/13/90	5920.4	7782.56	5920.53	04/12/90	5905.7	7782.56	5904.75
3/18/91	5917.0	8119.29	5920.53	03/18/91	5898.5	8119.29	5904.74
6/11/91	5917.5	8210.60	5920.52	06/05/91	5901.1	8210.60	5904.74
11/5/91	5916.3	8357.74	5920.52	11/05/91	5896.6	8357.74	5904.74
4/1/92	5918.5	8492.06	5927.53	04/06/92	5901.8	8492.06	5911.51
5/13/93	5917.3	8897.21	5917.25	05/14/93	5901.6	8897.21	5900.88
				Average Differences			
				Maximum Differences			
				Minimum Differences			
				Average Gradients ^d			
				Maximum Gradients ^d			
				Minimum Gradients ^d			
				Water Level Difference			
				Observed (ft)			
				Simulated (ft)			
				15.3			
				17.4			
				14.7			
				18.5			
				16.4			
				19.7			
				16.7			
				15.7			
				16.8			
				19.7			
				14.7			
				0.133			
				0.156			
				0.117			

Date of measurement of observed water level

^b Time of simulated water level

Difference in water levels

^d Gradients are calculated from water level differences (average minimum and maximum) divided by the distance between Well 4387 and Well 0487 (126 ft)

Table B-2b
Simulated and Observed Hydraulic Gradients

Well 0487					Well 4787					Water Level Difference	
Date of Water Level ^a	Observed Water Level (ft)	Model Time ^b (days)	Simulated Water Level (ft)		Date of Water Level ^a	Observed Water Level (ft)	Model Time ^b (days)	Simulated Water Level (ft)		Observed (ft)	Simulated (ft)
06/09/89	5902 0	7480 10	5904 76		06/10/89	5877 3	7480 10	5880 11		24 7	24 6499
01/16/90	5899 2	7691 25	5904 76		01/16/90	5878 4	7691 25	5880 10		20 8	24 6597
04/12/90	5905 7	7782 56	5904 75		04/12/90	5876 4	7782 56	5880 10		29 3	24 6499
03/18/91	5898 5	8119 29	5904 74		04/01/91	DRY	8119 29	5880 09			24 6504
06/05/91	5901 1	8210 60	5904 74		06/05/91	5877 2	8210 60	5880 08		23 9	24 6601
11/05/91	5896 6	8357 74	5904 74		11/05/91	5875 0	8357 74	5880 08		21 6	24 6601
04/06/92	5901 8	8492 06	5911 51		04/06/92	DRY	8492 06	5878 96		—	32 5498
05/14/93	5901 6	8897 21	5900 88		No good match		8897 21	5872 18		—	28 6997
					Average Differences					24 06	26 15
					Maximum Differences					29 3	32 5498
					Minimum Differences					20 8	24 6499
					Average Gradients ^d					0 134	0 145
					Maximum Gradients ^d					0 163	0 181
					Minimum Gradients ^d					0 116	0 137

Date of measurement of observed water level

^b Time of simulated water level

Difference in water levels

^d Gradients are calculated from water level differences (average minimum and maximum) divided by the distance between Well 0487 and Well 4787 (180 ft)

Table B-2c
Simulated and Observed Hydraulic Gradients

Well 4787				Well 5587				Water Level Difference	
Date of Water Level ^a	Observed Water Level (ft)	Model Time ^b (days)	Simulated Water Level (ft)	Date of Water Level ^a	Observed Water Level (ft)	Model Time ^b (days)	Simulated Water Level (ft)	Observed (ft)	Simulated (ft)
06/10/89	5877 3	7480 10	5880 11	06/01/89	5850 7	7480 10	5856 77	26 6	23 3399
01/16/90	5878 4	7691 25	5880 10	01/16/90	DRY	7691 25	5856 77		23 3301
04/12/90	5876 4	7782 56	5880 10	04/12/90	5853 5	7782 56	5856 77	22 9	23 3301
04/01/91	DRY	8119 29	5880 09	04/01/91	DRY	8119 29	5856 77		23 3198
06/05/91	5877 2	8210 60	5880 08	06/05/91	5850 7	8210 60	5856 77	26 5	23 3101
11/05/91	5875 0	8357 74	5880 08	11/05/91	5850 6	8357 74	5856 77	24 4	23 3101
04/06/92	DRY	8492 06	5878 96	04/01/92	5853 6	8492 06	5858 49		20 4698
No good match		8897 21	5872 18	05/14/93	5850 9	8897 21	5855 63		16 5503
				Average	Differences			25 1	22 12
				Maximum	Differences			26 6	23 3399
				Minimum	Differences			22 9	16 5503
				Average	Gradients ^d			0 155	0 137
				Maximum	Gradients ^d			0 164	0 144
				Minimum	Gradients ^d			0 141	0 102

Date of measurement of observed water level

^b Time of simulated water level

Difference in water levels

^d Gradients are calculated from water level differences (average minimum and maximum) divided by the distance between Well 4787 and Well 5587 (162 ft)

Table B-3
Parameters Analyzed in Sensitivity Analysis

Parameter	Units	Sensitivity Analysis		Baseline	
		Colluvium	Alluvium	Colluvium	Alluvium
Distribution coefficient (Kd)	L/mg	4 77	4 77	4 34	4 34
Distribution coefficient (Kd)	L/mg	3 906	3 906	4 34	4 34
Half life	days	0	0	370 5	370 5
Porosity		0 18	0 225	0 36	0 45
Horizontal hydraulic conductivity (Kxx) ¹	ft/day (m/day)	0 12 (0 037)	4 8 (1 463)	0 45 (0 137)	6 0 (1 829)
Horizontal hydraulic conductivity (Kxx) ¹	ft/day (m/day)	1 2 (0 366)	7 2 (2 195)	0 45 (0 137)	6 0 (1 829)

¹ The ratio of horizontal to vertical hydraulic conductivities was kept the same for the sensitivity analysis as it was for the baseline model runs

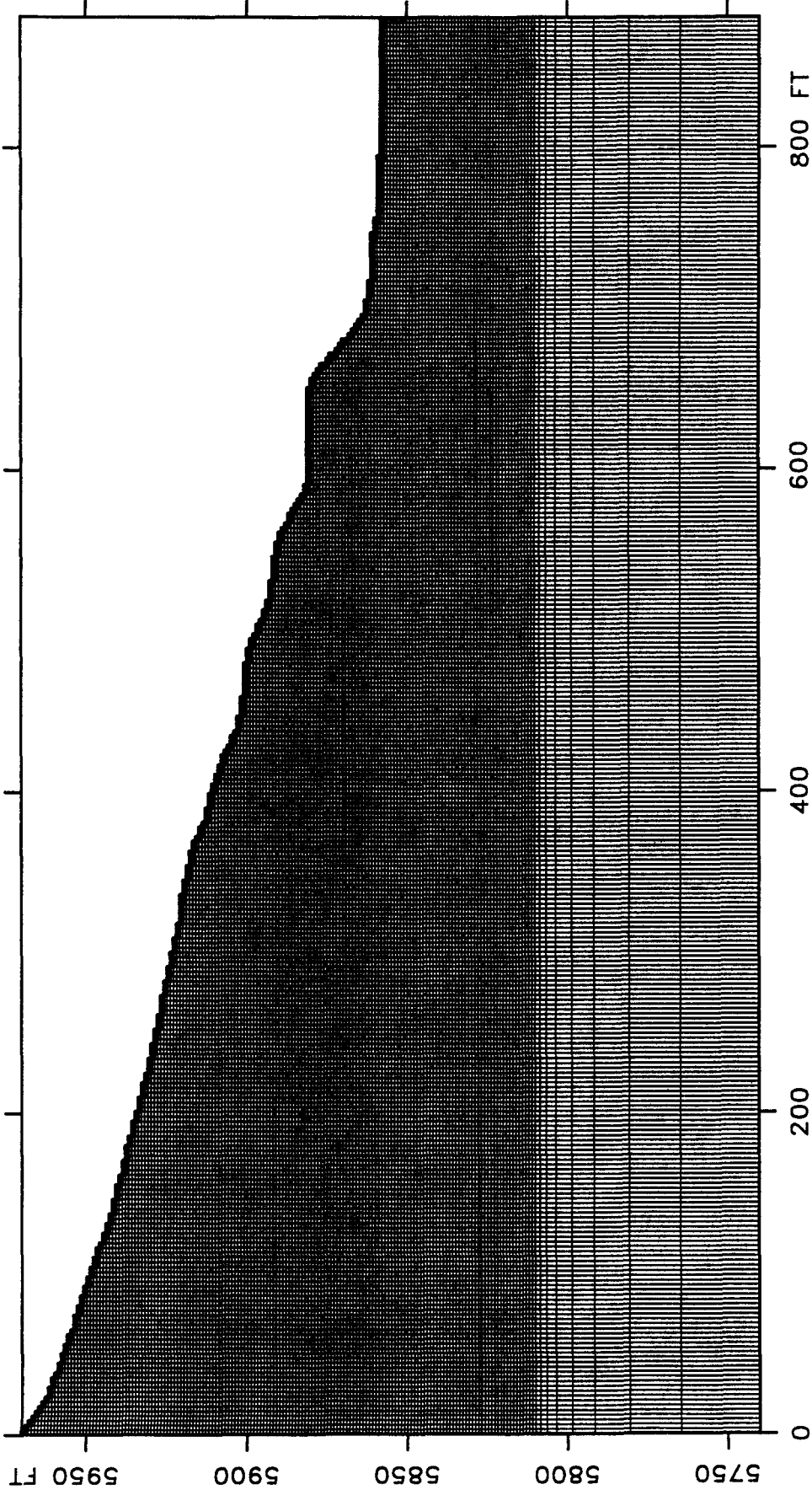
Table B-4
Model Assumptions and Uncertainty Factors

Model assumption or uncertainty factor	Cause of uncertainty or model error	Probable effect on model results	Relative degree of uncertainty
Two-dimensional model	Three-dimensional transport not simulated	Incorrect spatial distribution of concentrations and flows	Low Model adequately matches general trends in the horizontal behavior of the observed plume Model is conservative due to underestimation of spreading transverse to model plane
Porous media	Flow in fractures or other secondary porosity not simulated	Incorrect spatial distribution of concentrations and fluxes	Low Although slip subsurface failure planes have been mapped (DOE 1994) it is likely that such potential pathways have healed and are no longer permeable
Steady state flow	Transient flow is not simulated for calibration	Incorrect spatial distribution of concentrations and flows	Low Contaminant transport and fluctuations in flow become less important over long periods of time The model is conservative in simulating continually saturated conditions where seasonal wetting and drying is known to occur
Material properties are homogeneous within a model layer	Heterogeneity within model layers	Incorrect spatial distribution of contaminants and flows	Low The primary hydrogeologic layers that affect transport are well characterized
Timing of release	Not well known	Incorrect spatial distribution of contaminants	Low Model is generally conservative Observed concentrations have generally reached a steady state condition suggesting that transport across the hillside has achieved steady state Therefore knowledge of the timing of release is not required to predict future conditions
Nature of release	Processes other than dissolution are not modeled	Incorrect spatial distribution of contaminants	Low Model is conservative and bounds observed concentrations

Sorption	Linear sorption	Incorrect spatial distribution of contaminants	Low Organic carbon content of subsurface materials is low
Natural recharge and discharge rates	Not measured	Incorrect spatial distribution of contaminants and flows	Moderate Model is sensitive to this parameter
Decay and transformation	Multi-component transport not simulated due to lack of site specific data	Incorrect spatial distribution of contaminants	Low Model is conservative
Porosity	Measurement error	Incorrect spatial distribution of contaminants	Low Measurement error relatively small
Diffusion coefficient	Not measured	Incorrect spatial distribution of contaminants	Low Error is small and model is insensitive to this parameter
Dispersivity	Not measured	Incorrect spatial distribution of contaminants	Moderate Parameter is based on scale of site this is a standard assumption
Size of source	Not measured	Incorrect spatial distribution of contaminants	Low Model has been assumed to be insensitive to source size (Fedors et al 1993)

NORTH

SOUTH

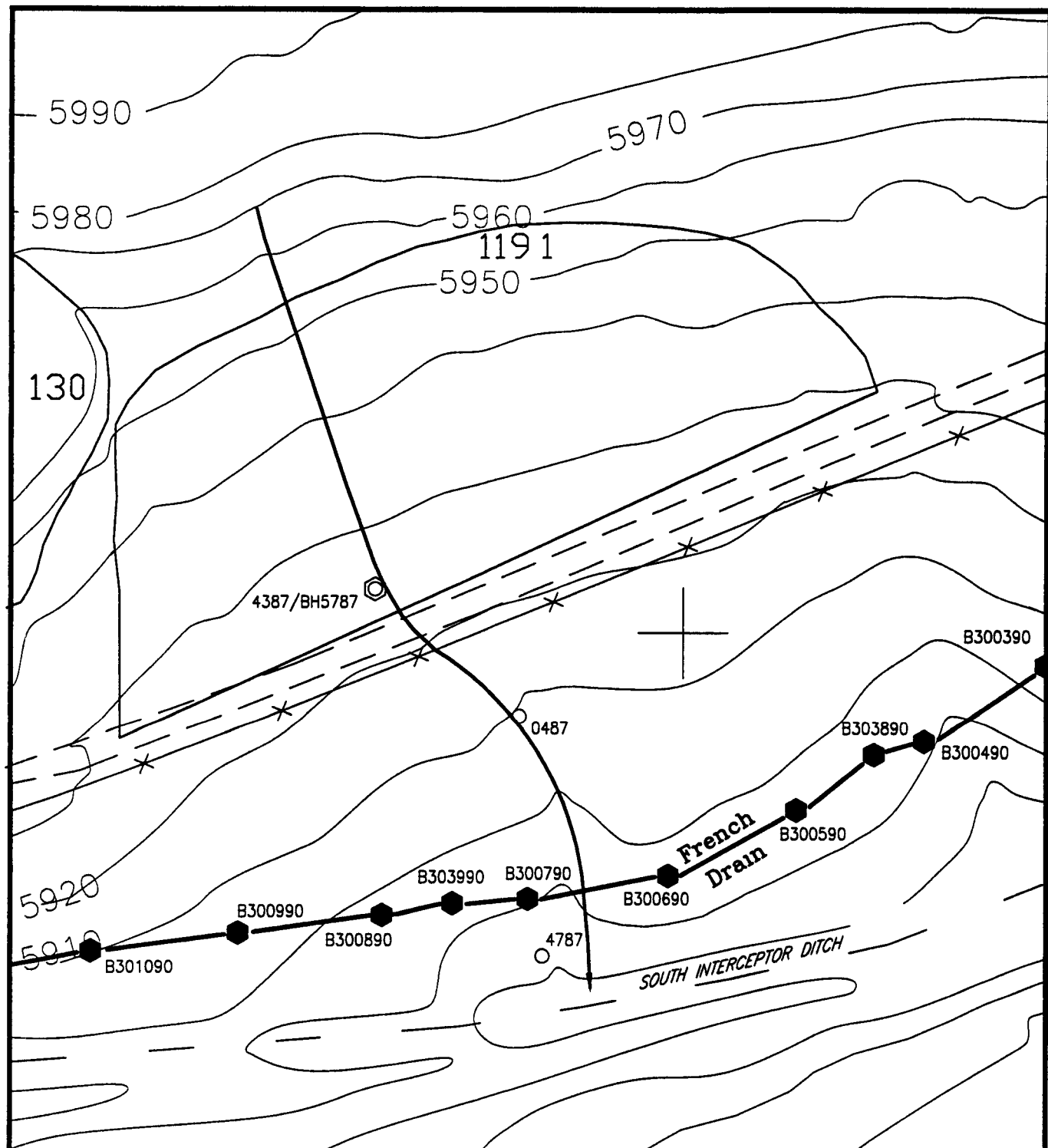


U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1

Model Discretization

Figure B-1



K:\DESIGN\ROCKYFLTS\HILL881\OU 1\HSS 119.DWG

EXPLANATION



INDIVIDUAL HAZARDOUS SUBSTANCE

- B301889
- BH1587
- B300390

ALLUVIAL WELL

BOREHOLE

FRENCH DRAIN BOREHOLES



CONTOUR INTERVAL = 10 FEET



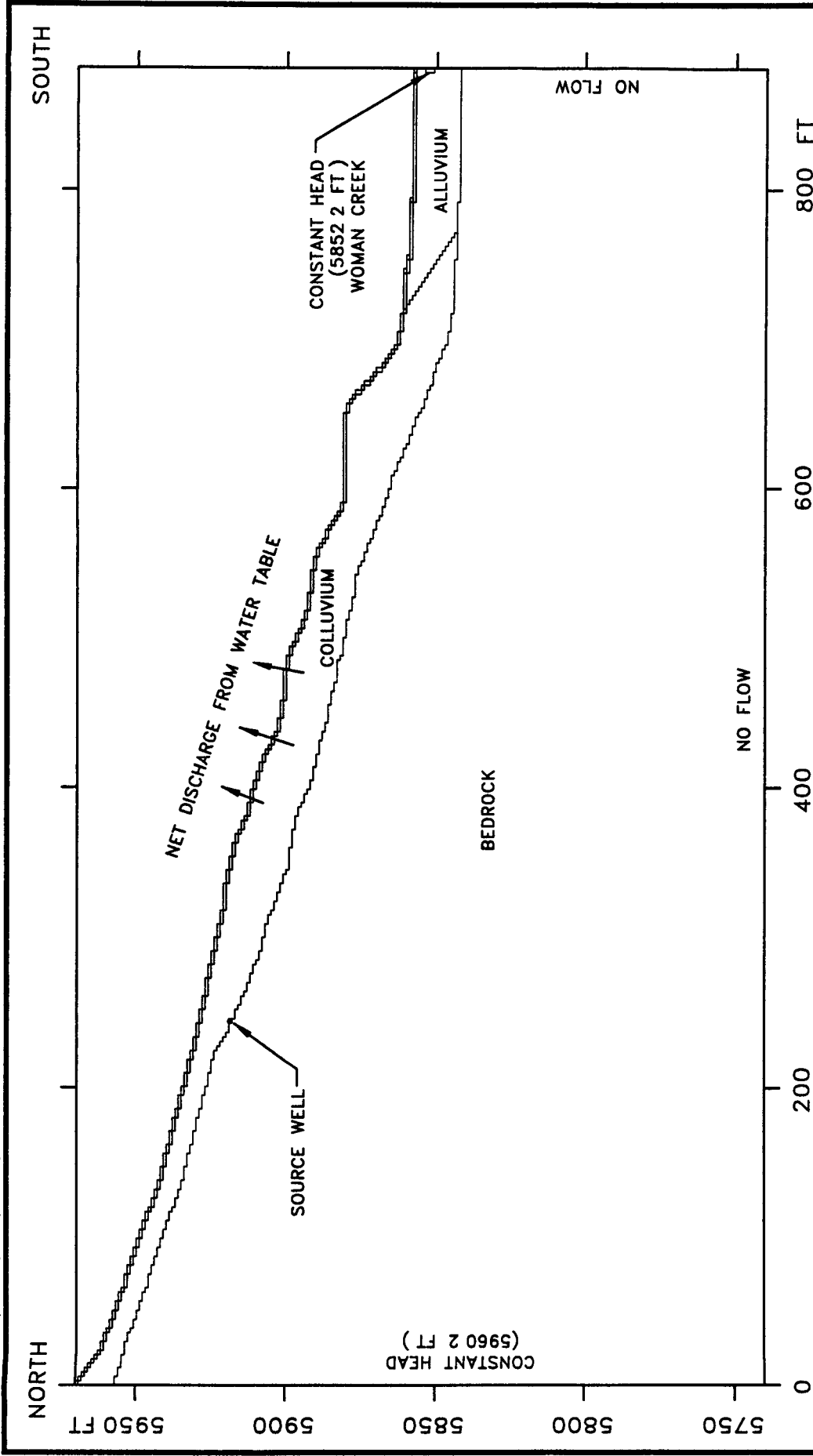
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Golden Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

Location of Model Section
in IHSS 119 1

Figure B-3

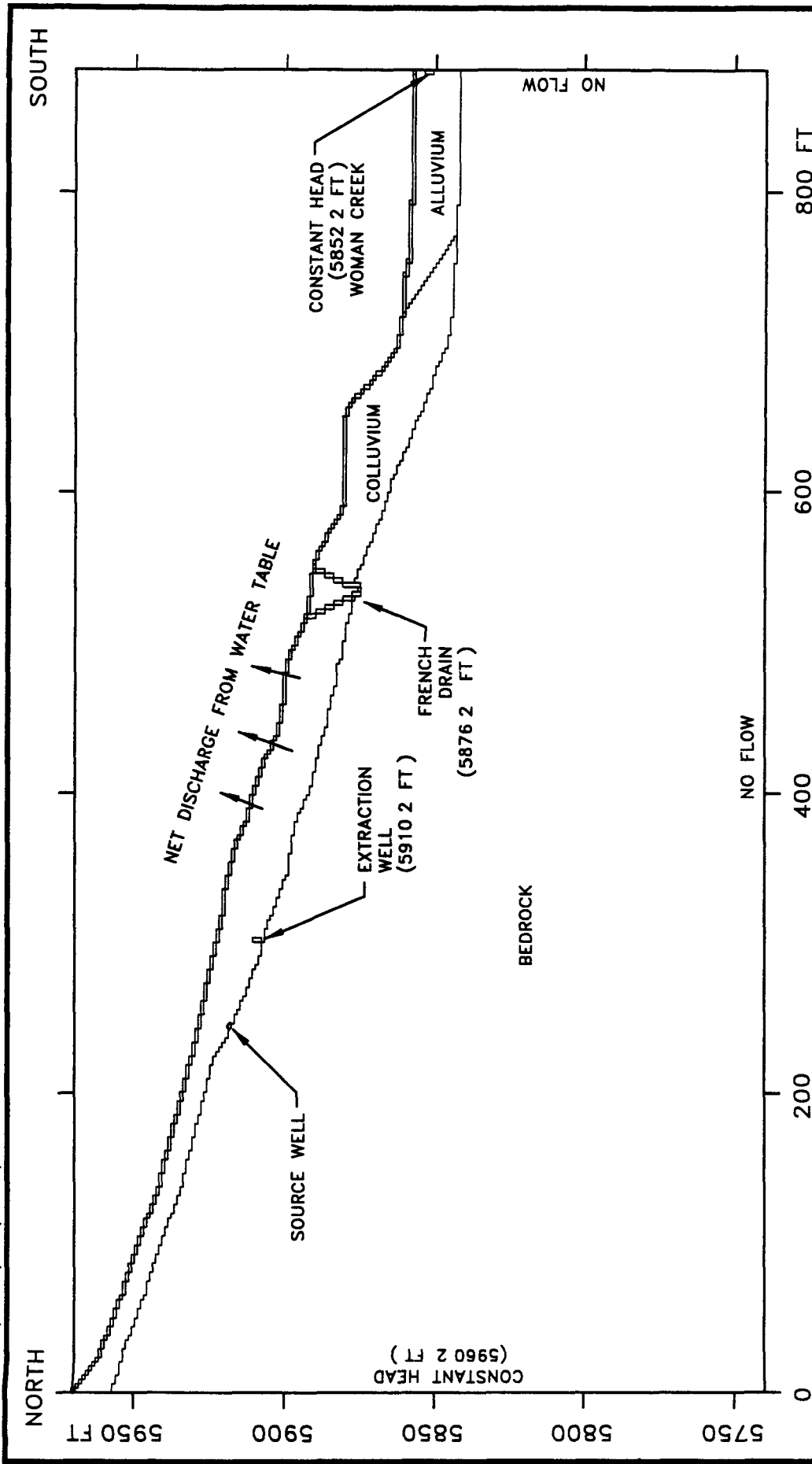


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881 HILLSIDE AREA
OPERABLE UNIT NO 1

Model Boundary Conditions
Steady State

Figure B-4

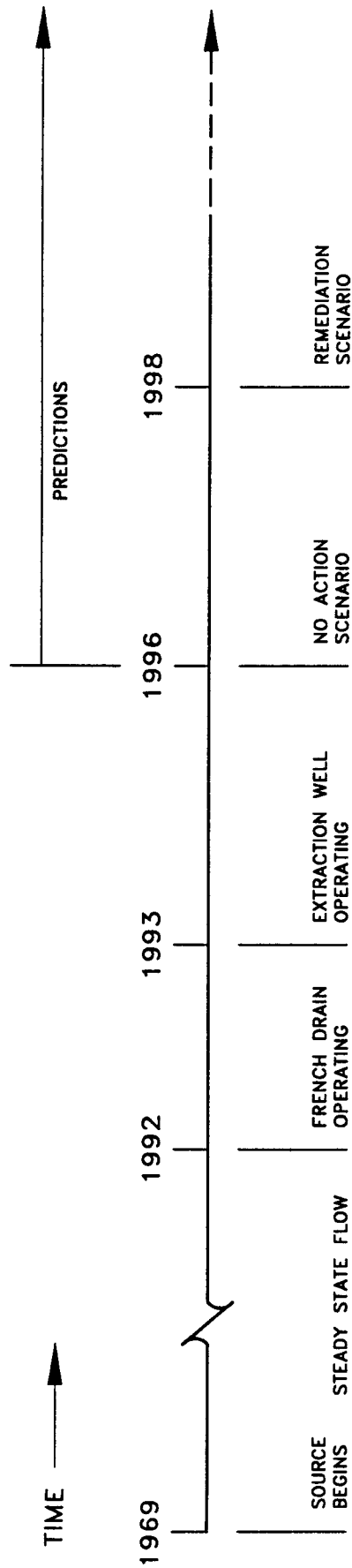


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Model Boundary Conditions
 Transient

Figure B-5



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Timeline

Figure B-6

Model vs Calculated Kr Colluvium

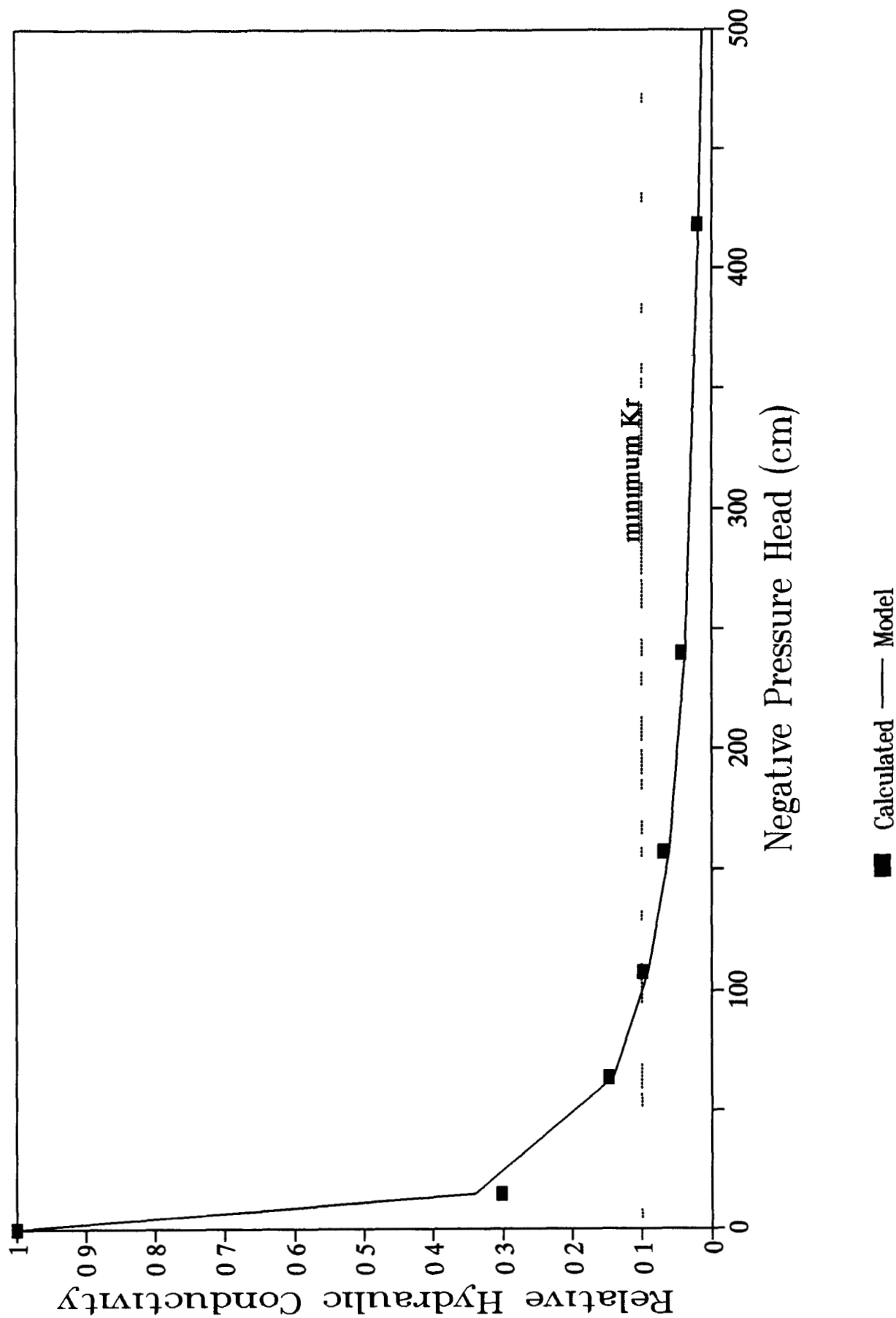
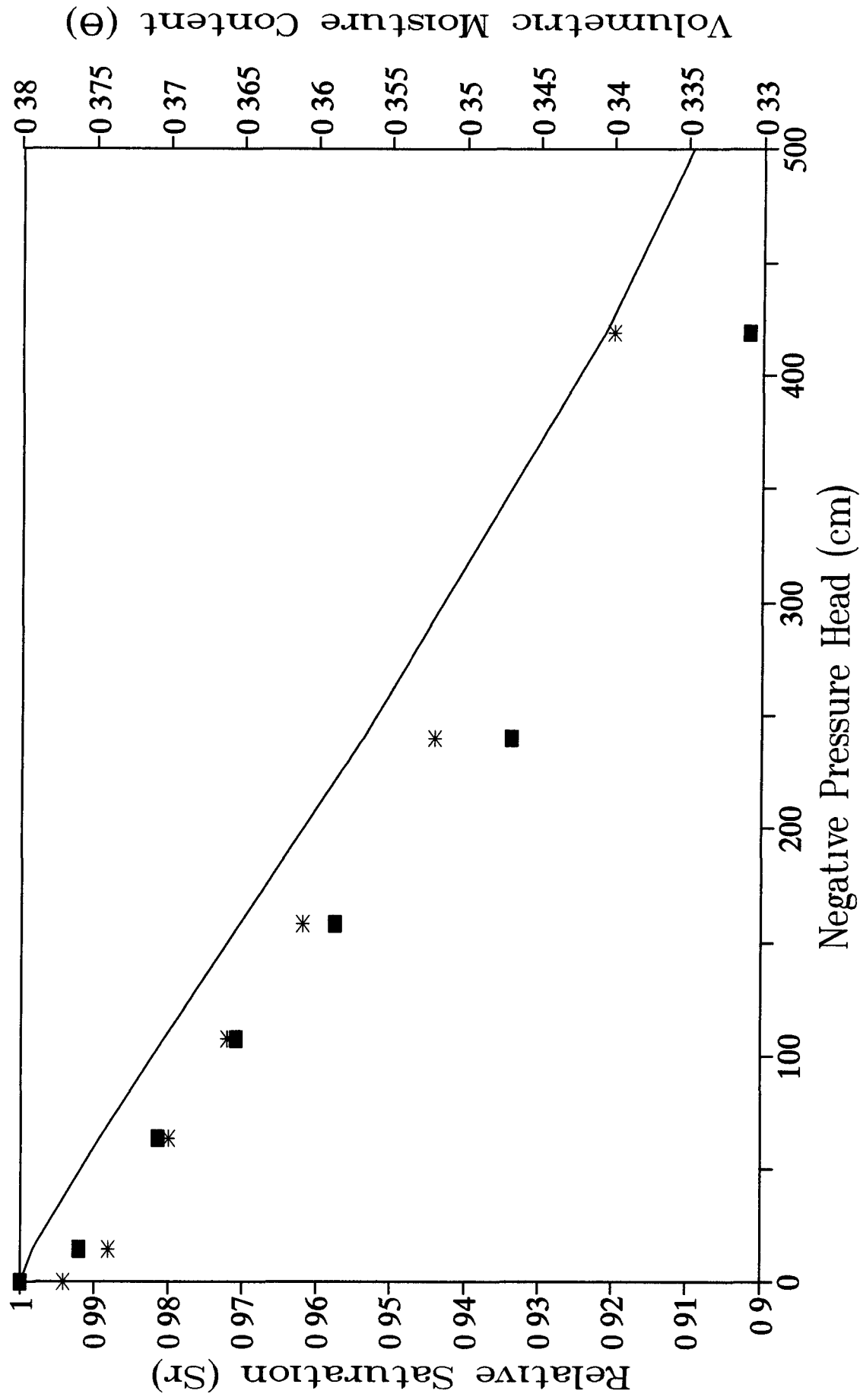


Figure B-7

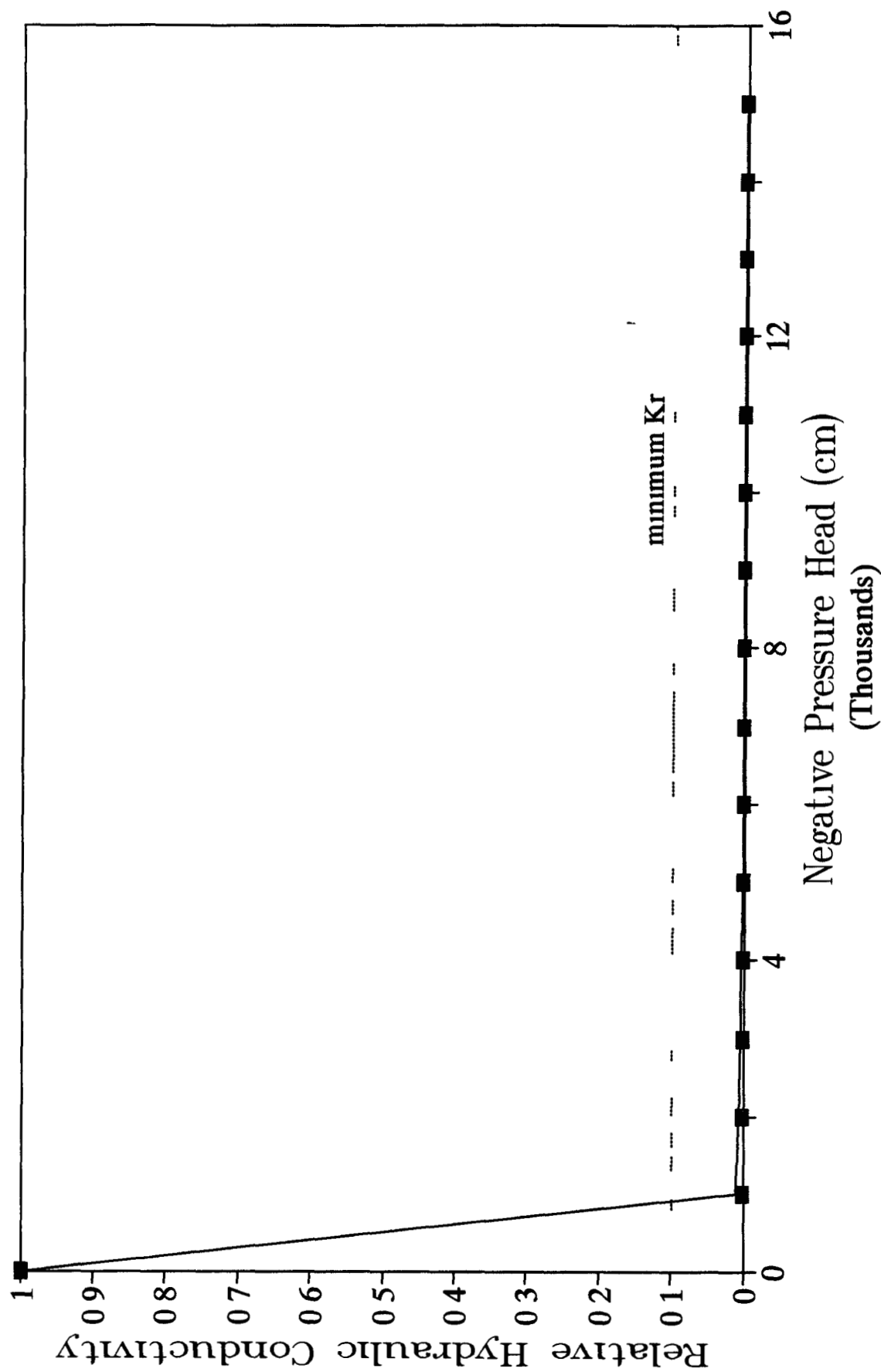
Model vs Measured Sr Colluvium



■ Measured Sr — Model Sr * Volumetric θ

Figure B-8

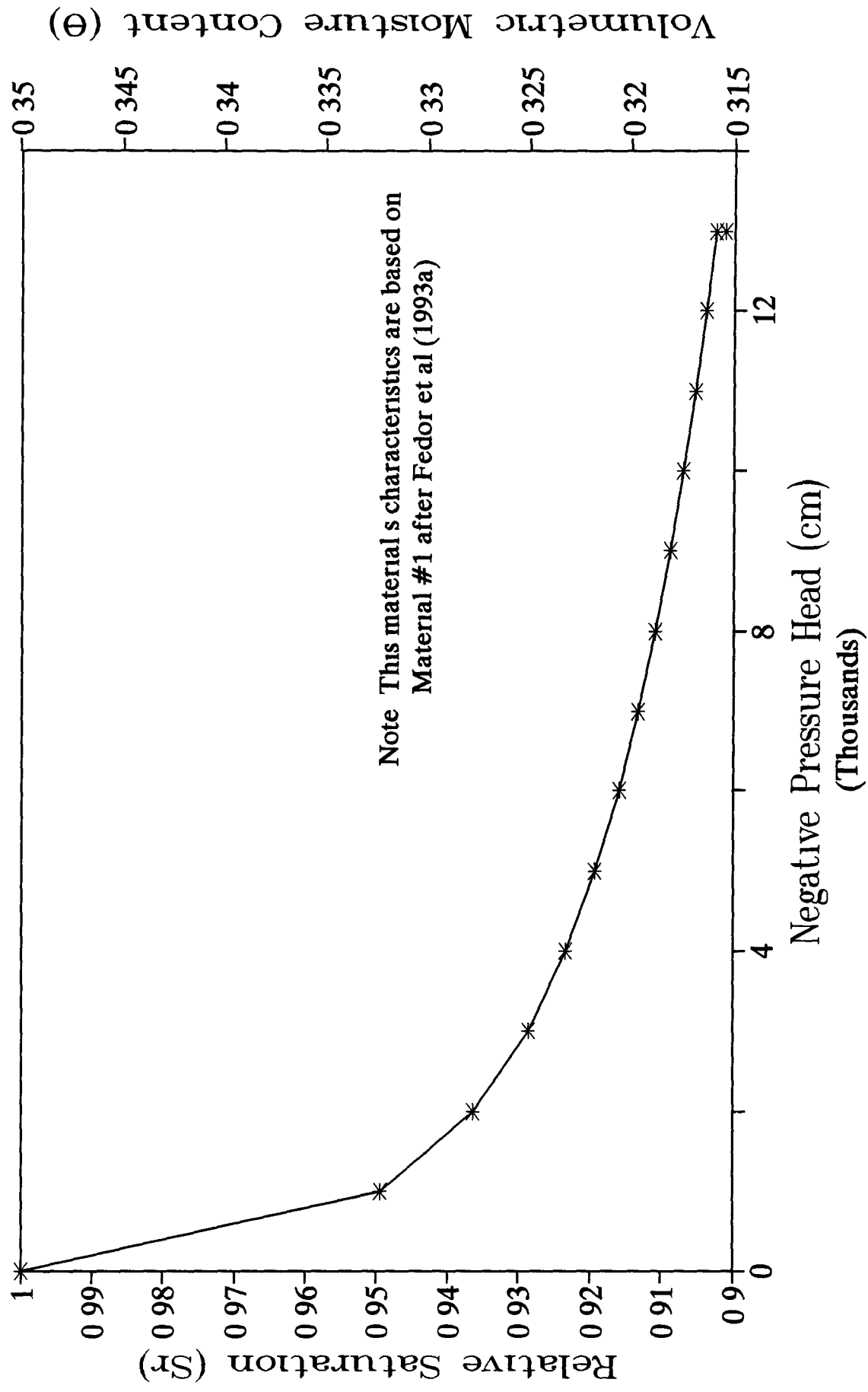
Model vs Calculated Kr Bedrock



■ Calculated — Model

Figure B 9

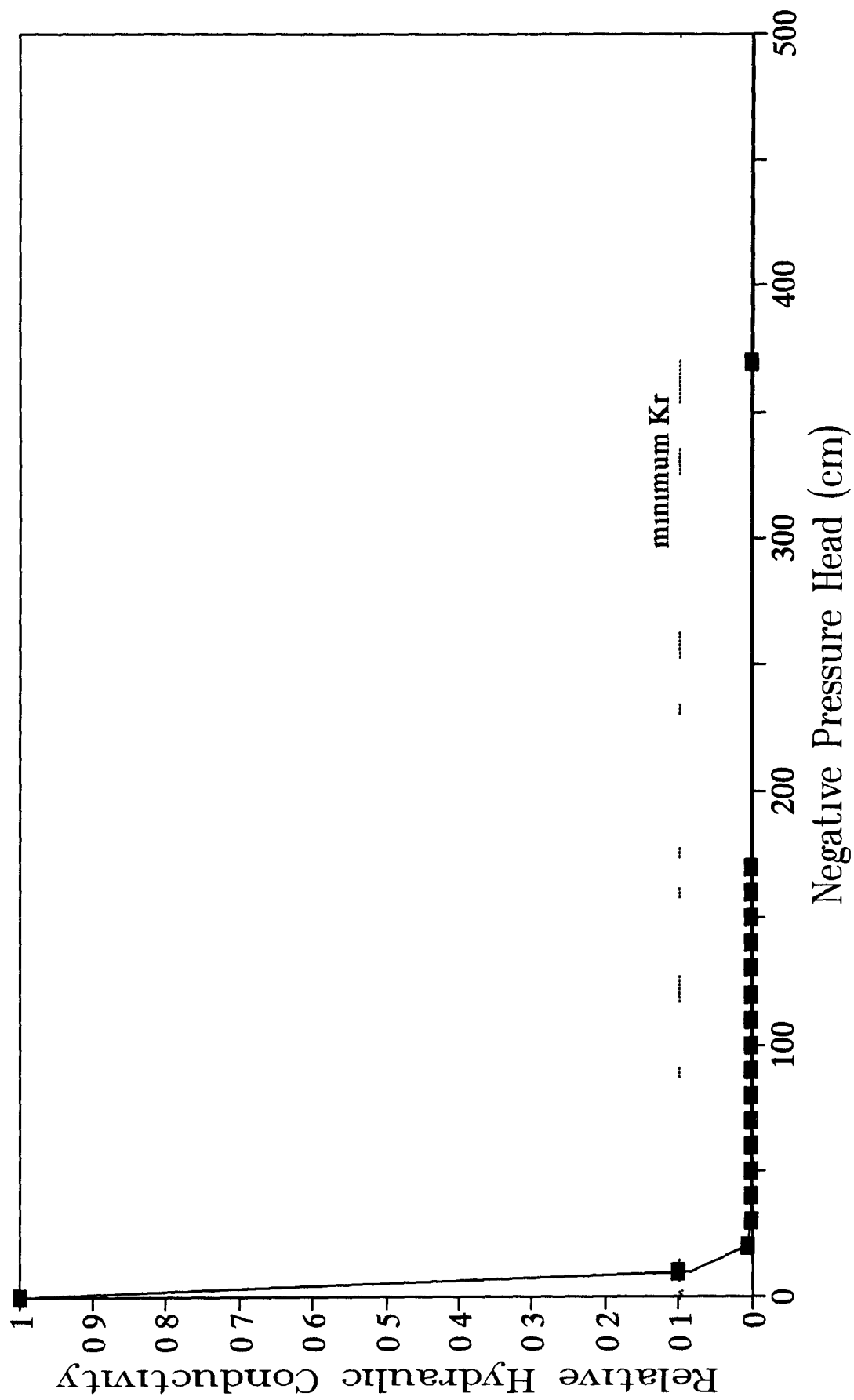
Model vs Measured Sr Bedrock



— Model Sr * Volumetric θ

Figure B-10

Model vs Calculated Kr Woman Creek Alluvium



■ Calculated — Target

Figure B-11

Model vs Measured Sr Woman Creek Alluvium

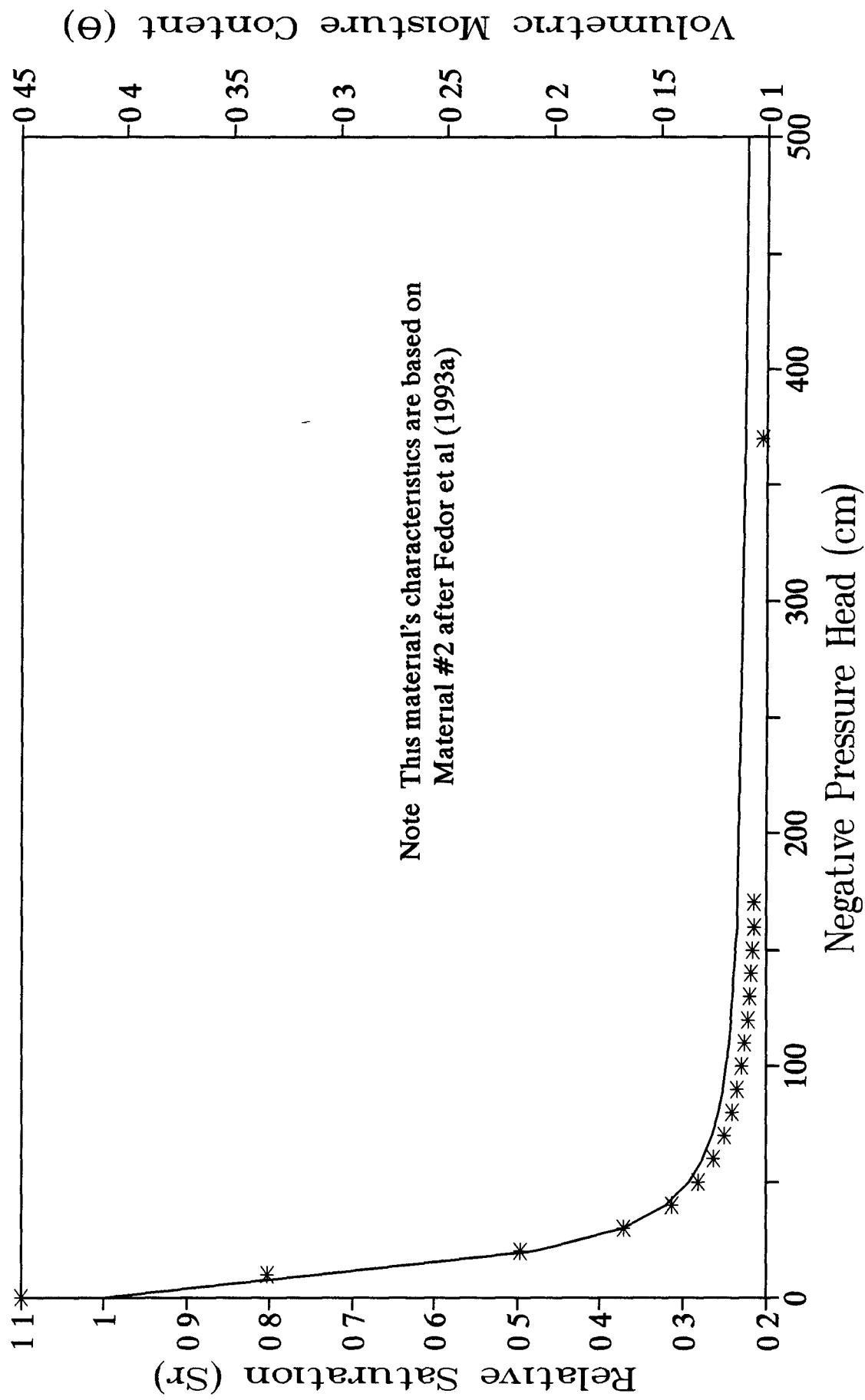


Figure B-12

— Model Sr * Volumetric θ

Water Level at Well 0487 Observed and Simulated

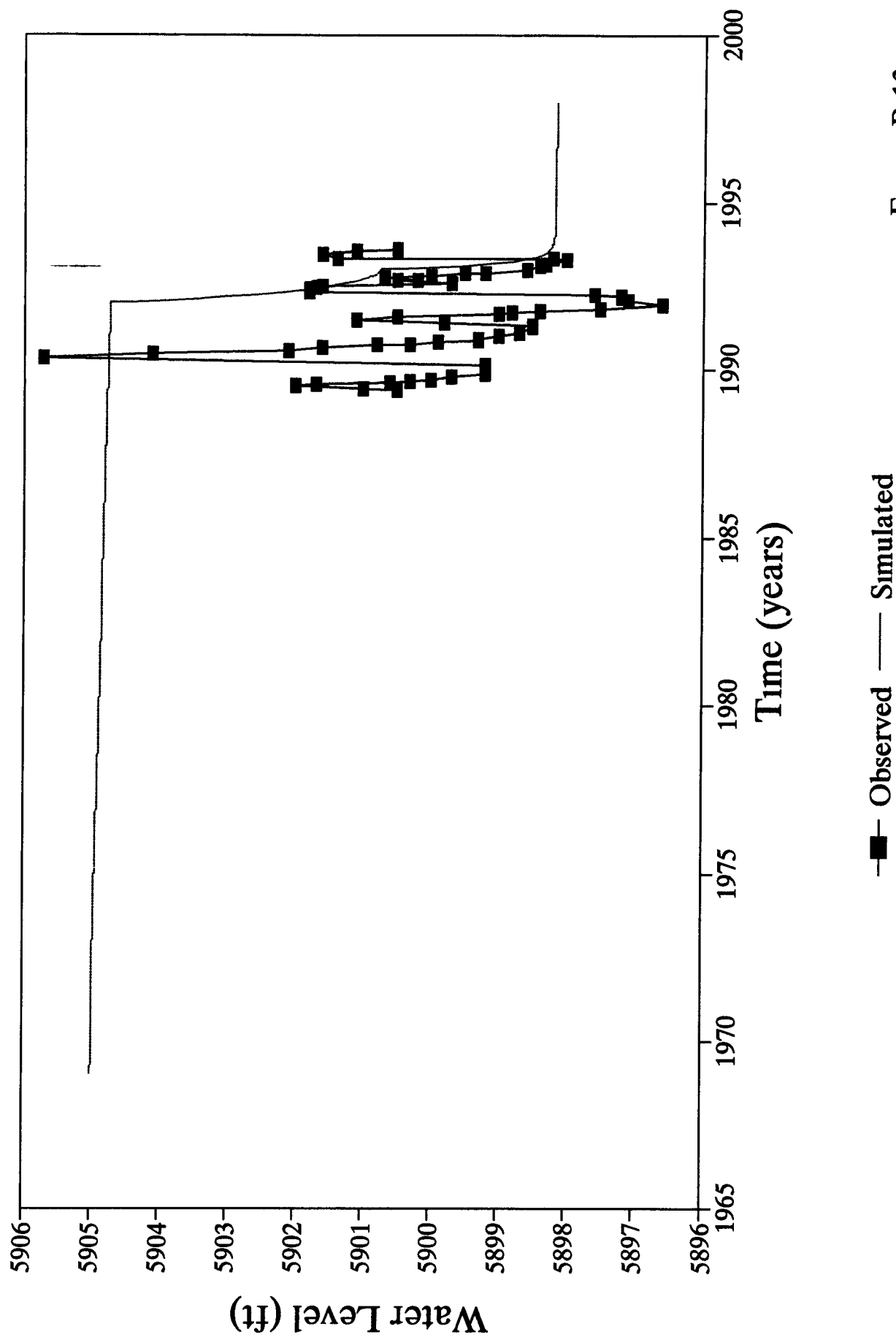
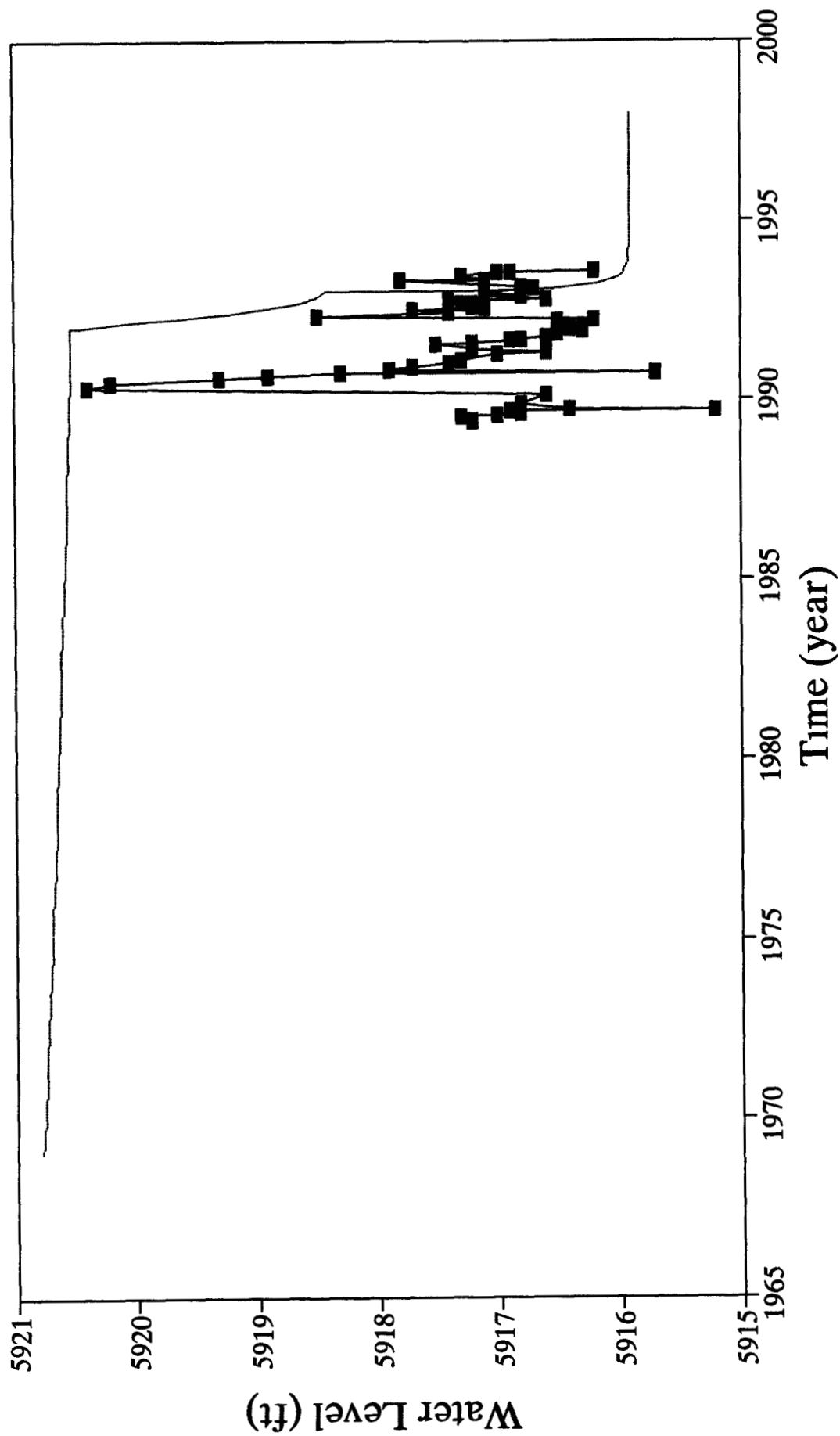


Figure B-13

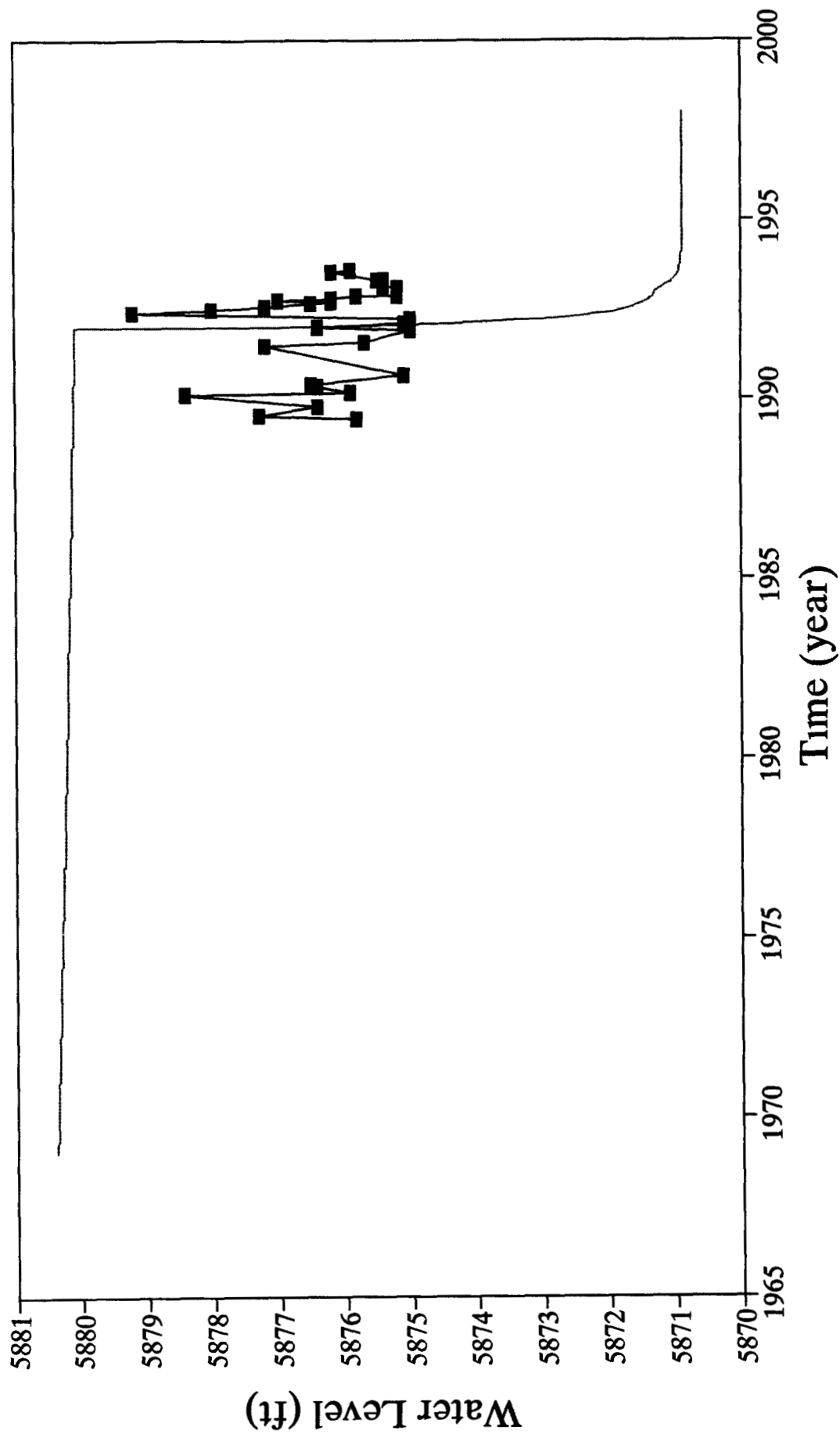
Water Level at Well 4387 Observed and Simulated



—■— Observed — Simulated

Figure B-14

Water Level at Well 4787 Observed and Simulated



—■— Observed — Simulated

Figure B 15

Water Level at Well 5587 Observed and Simulated

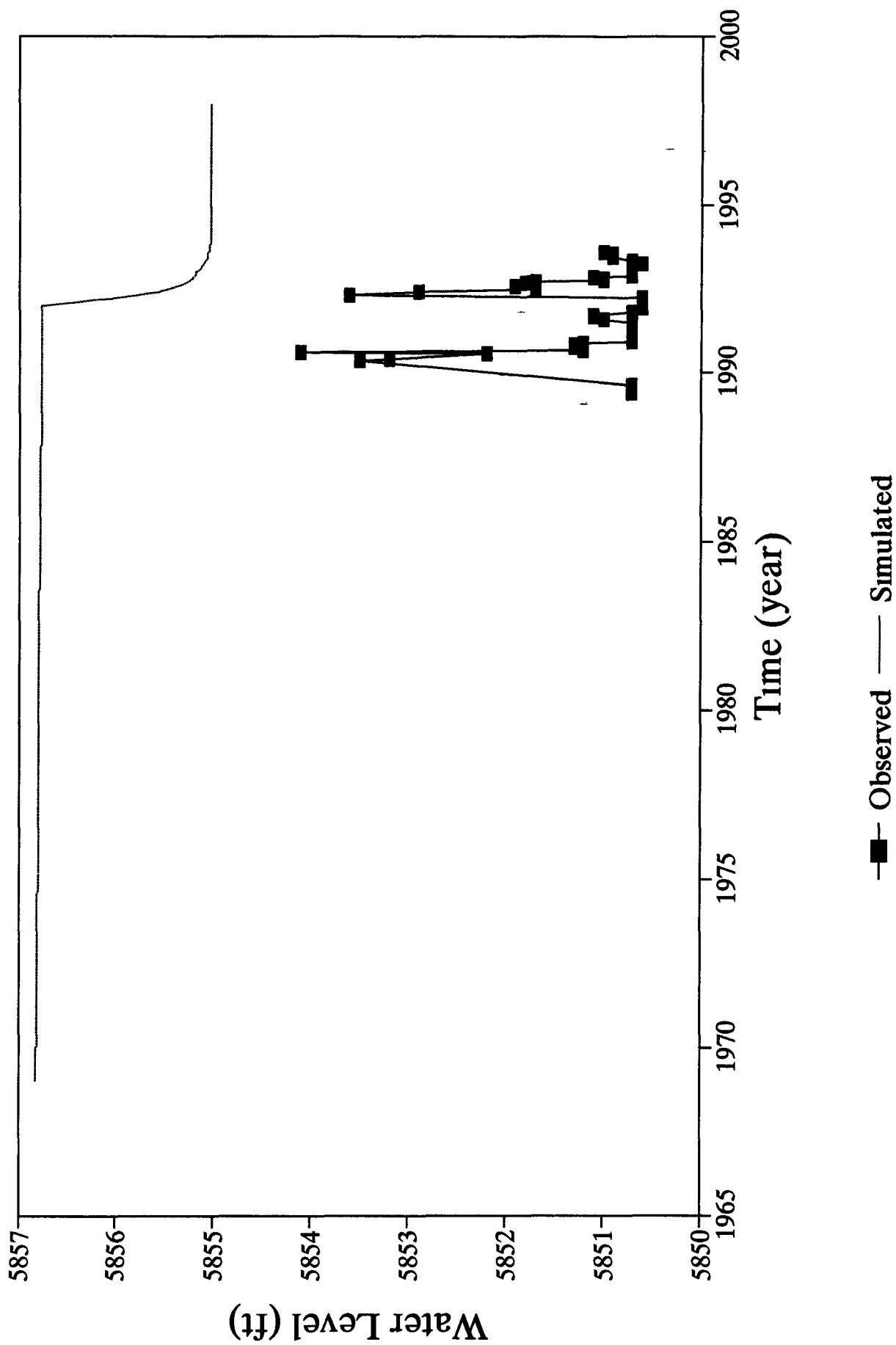


Figure B-16

Flow Mass Balance

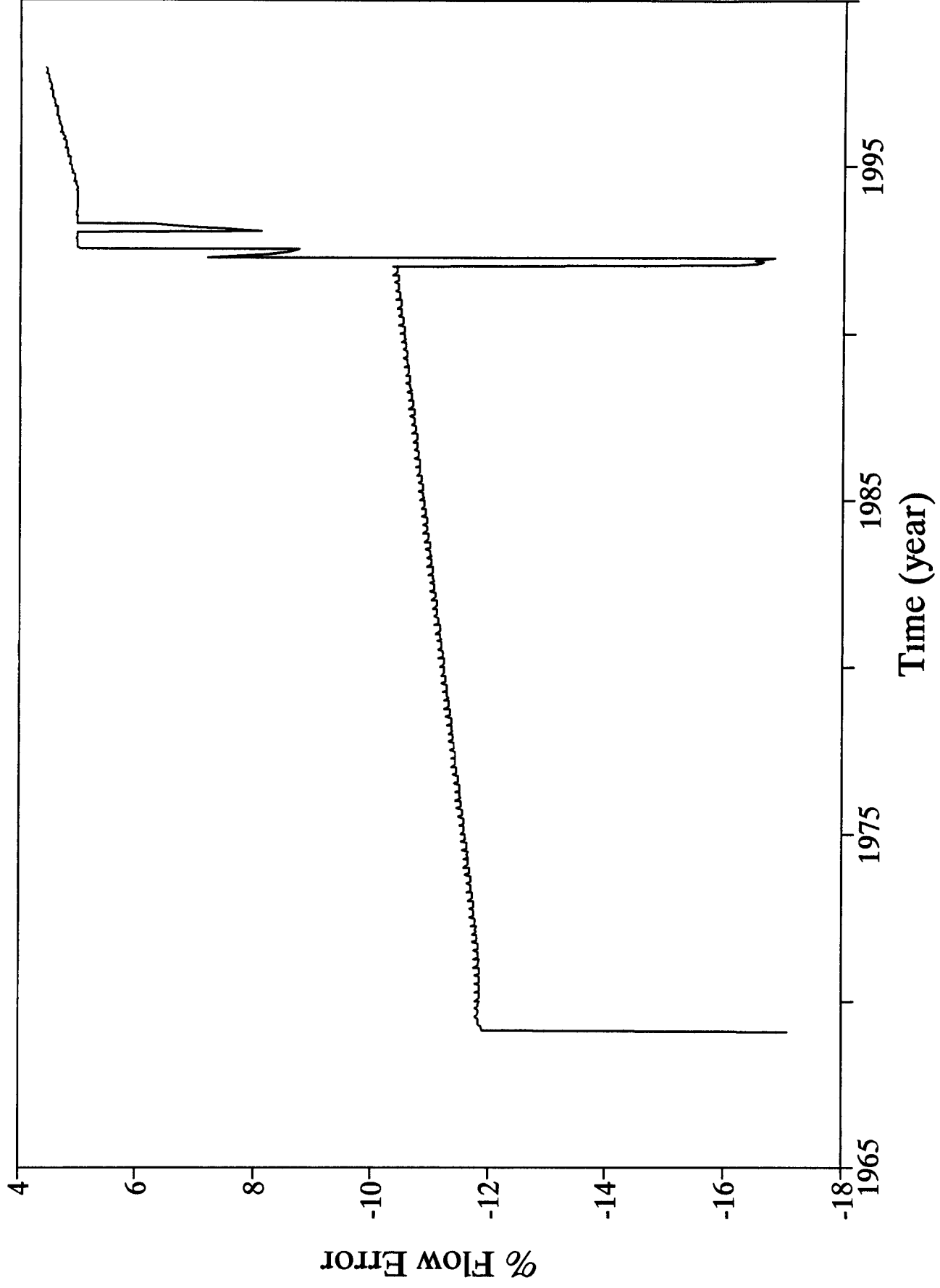


Figure B 17

Convergence Behavior of Flow Through 1997

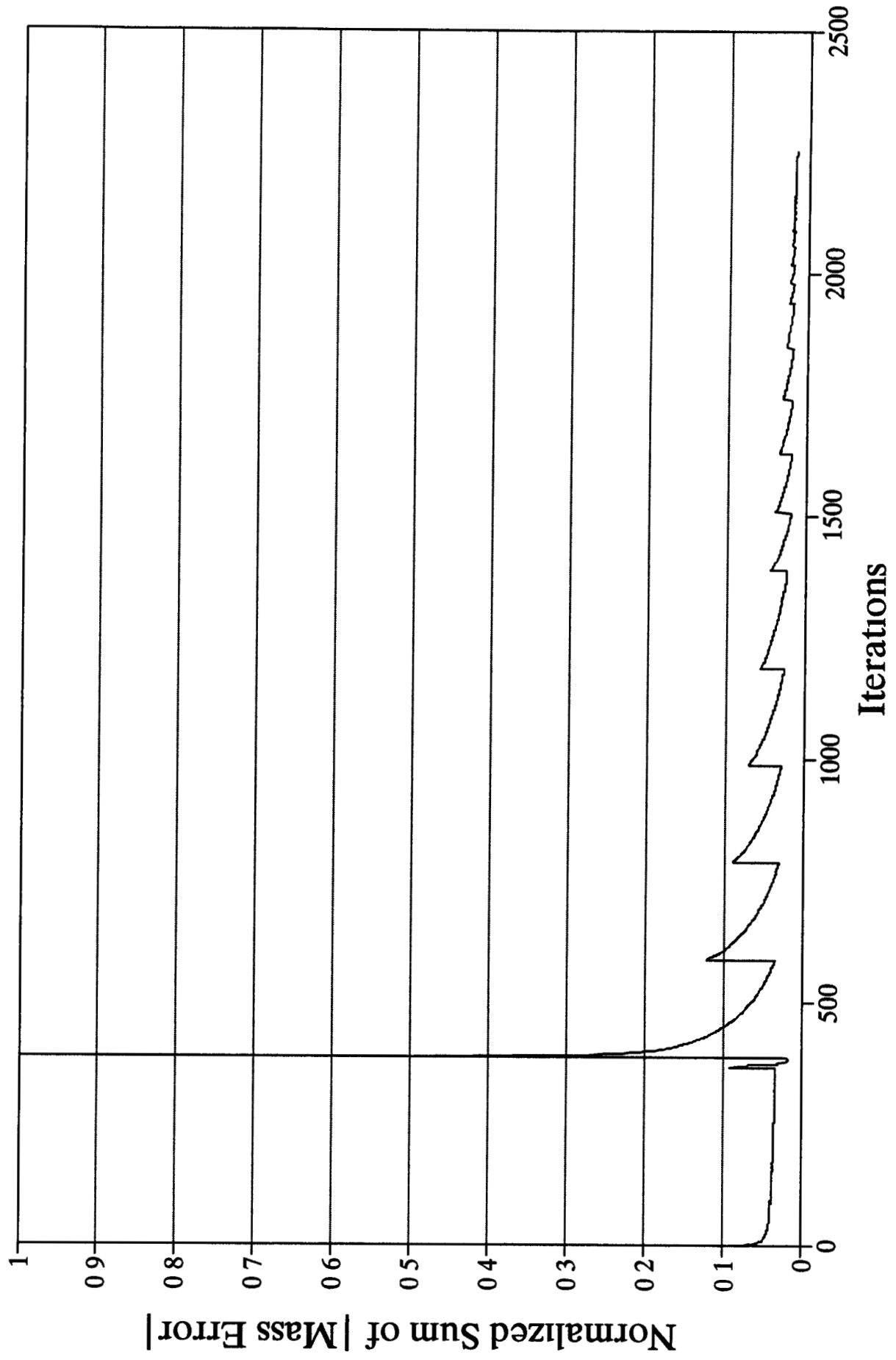


Figure B-18

TCE Mass Balance

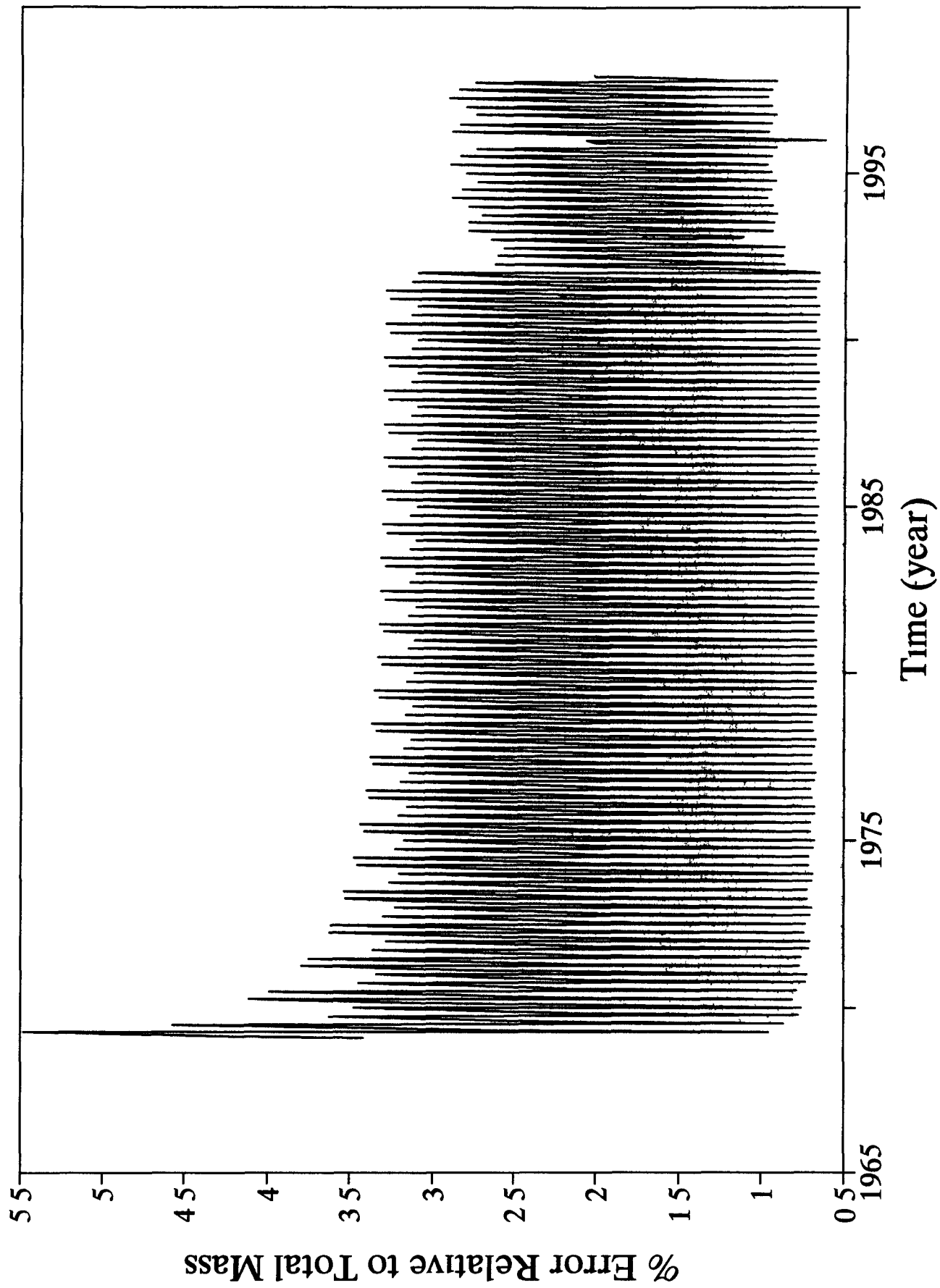


Figure B 19

Convergence Behavior of TCE Concentrations Through 1997

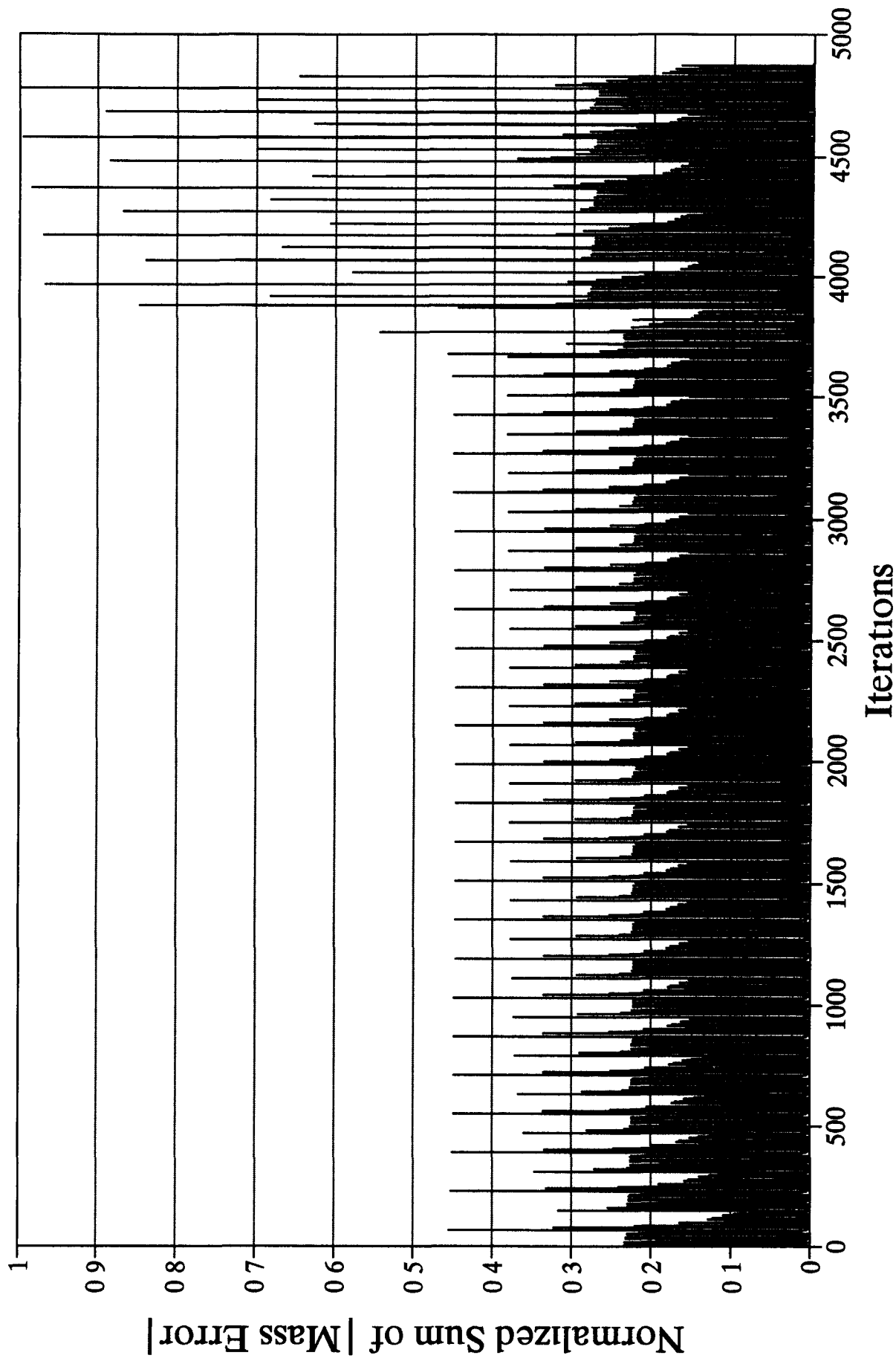


Figure B-20

PCE Calibration of Well 0487

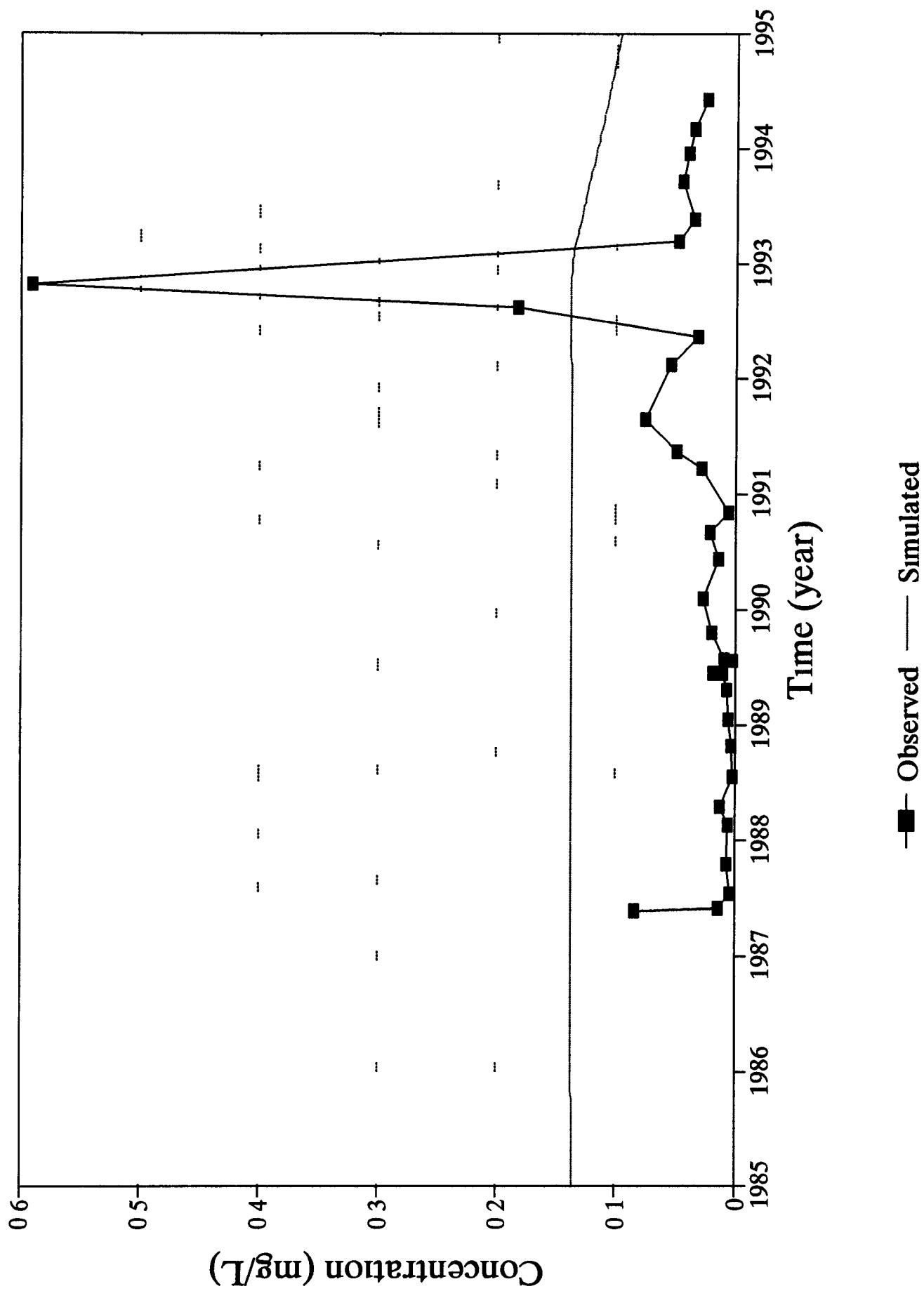


Figure B-21

PCE Calibration of Well 4387

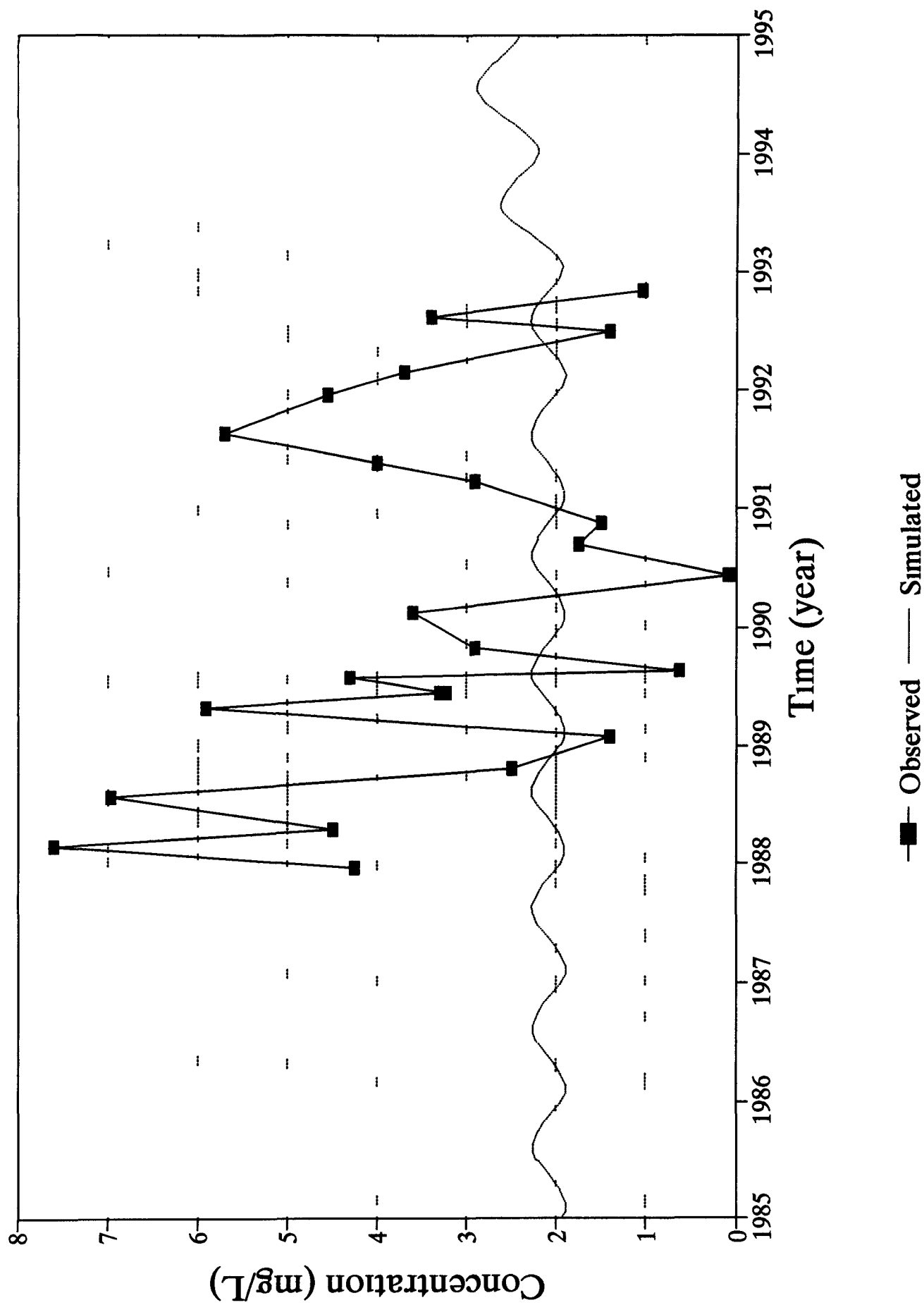
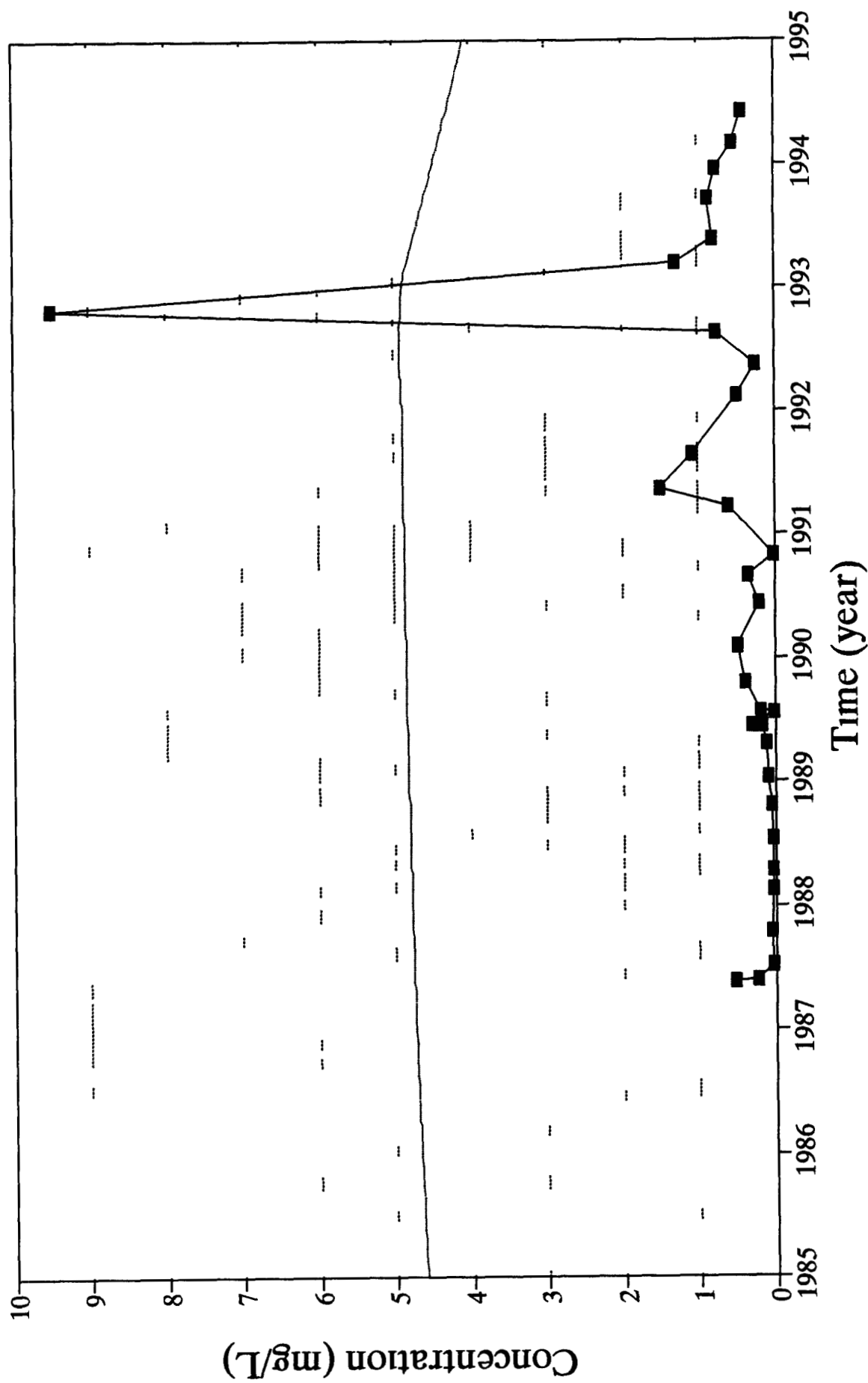


Figure B-22

TCE Calibration of Well 0487



■ Observed — Simulated

Figure B-23

TCE Calibration of Well 4387

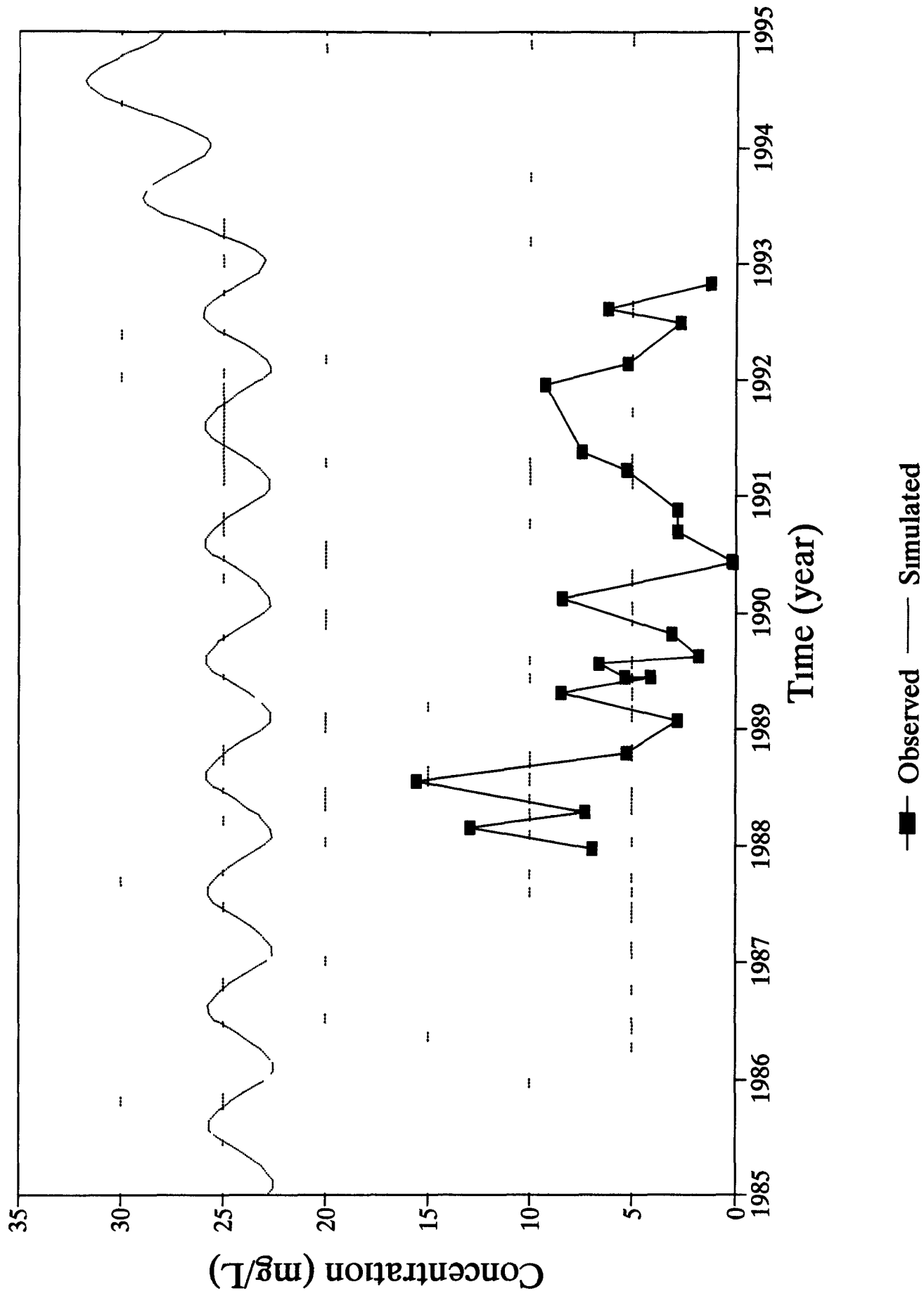


Figure B-24

1,1,1-TCA Calibration of Well 0487

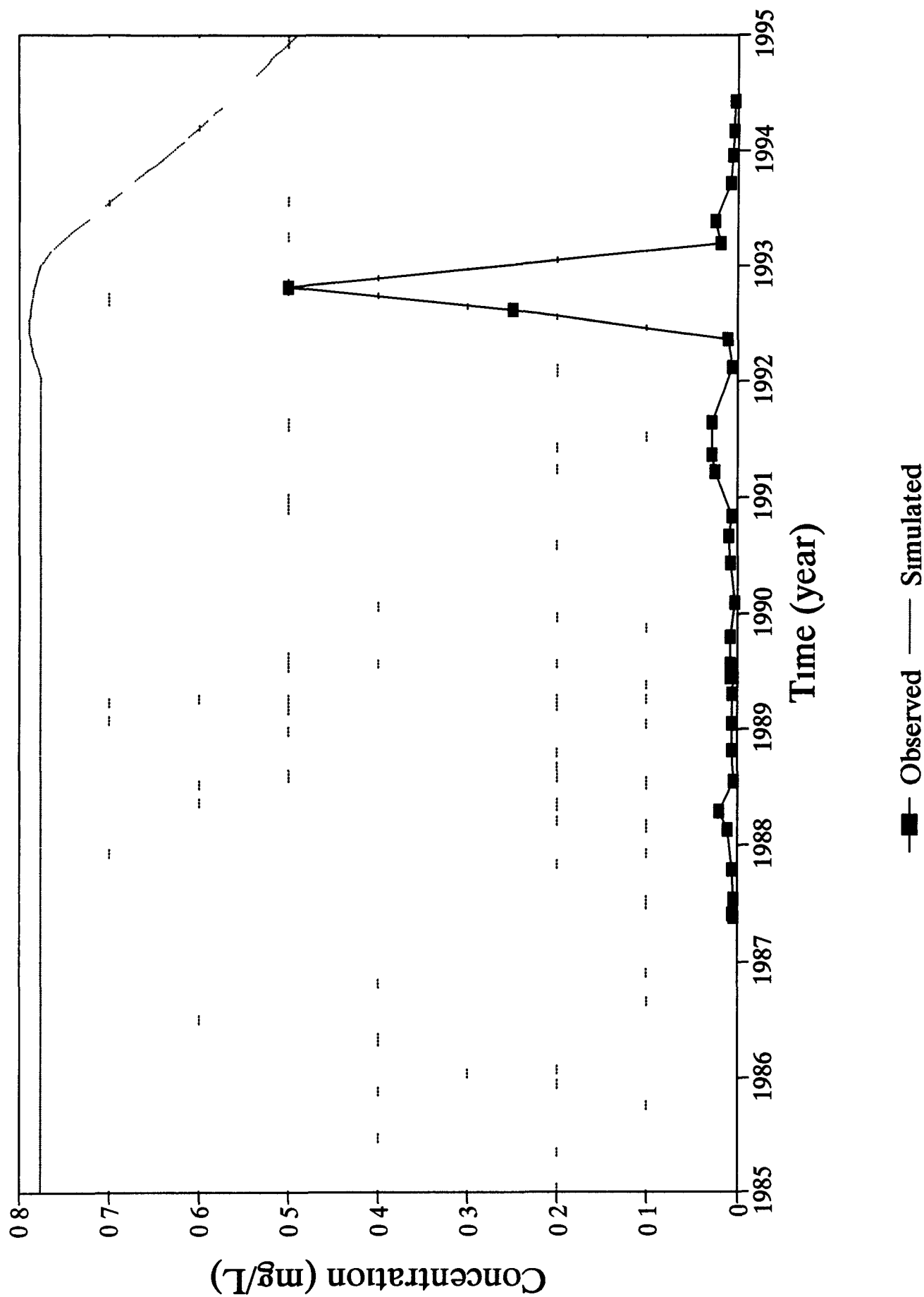


Figure B-25

1,1,1-TCA Calibration of Well 4387

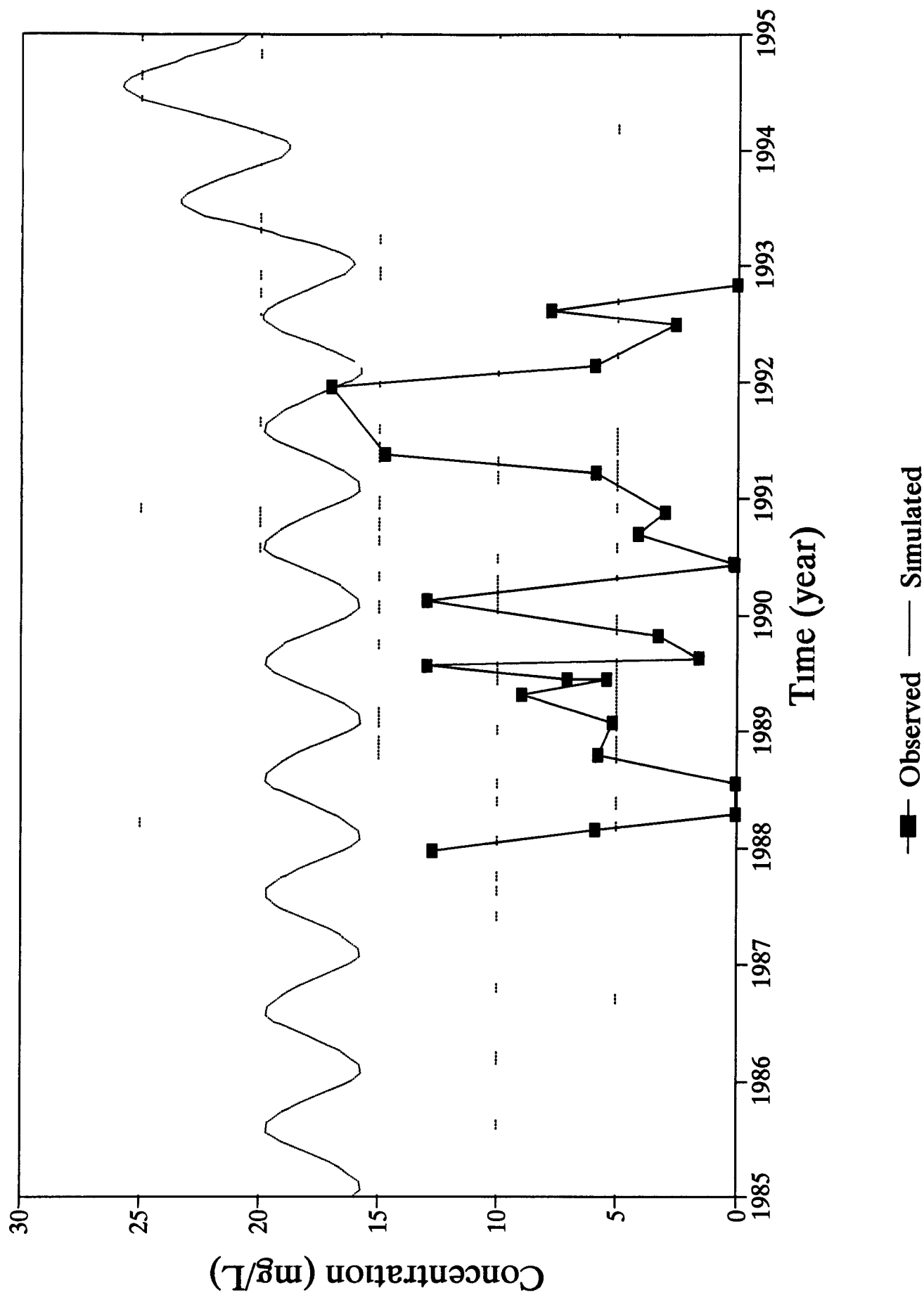


Figure B-26

1,1-DCE Calibration of Well 0487

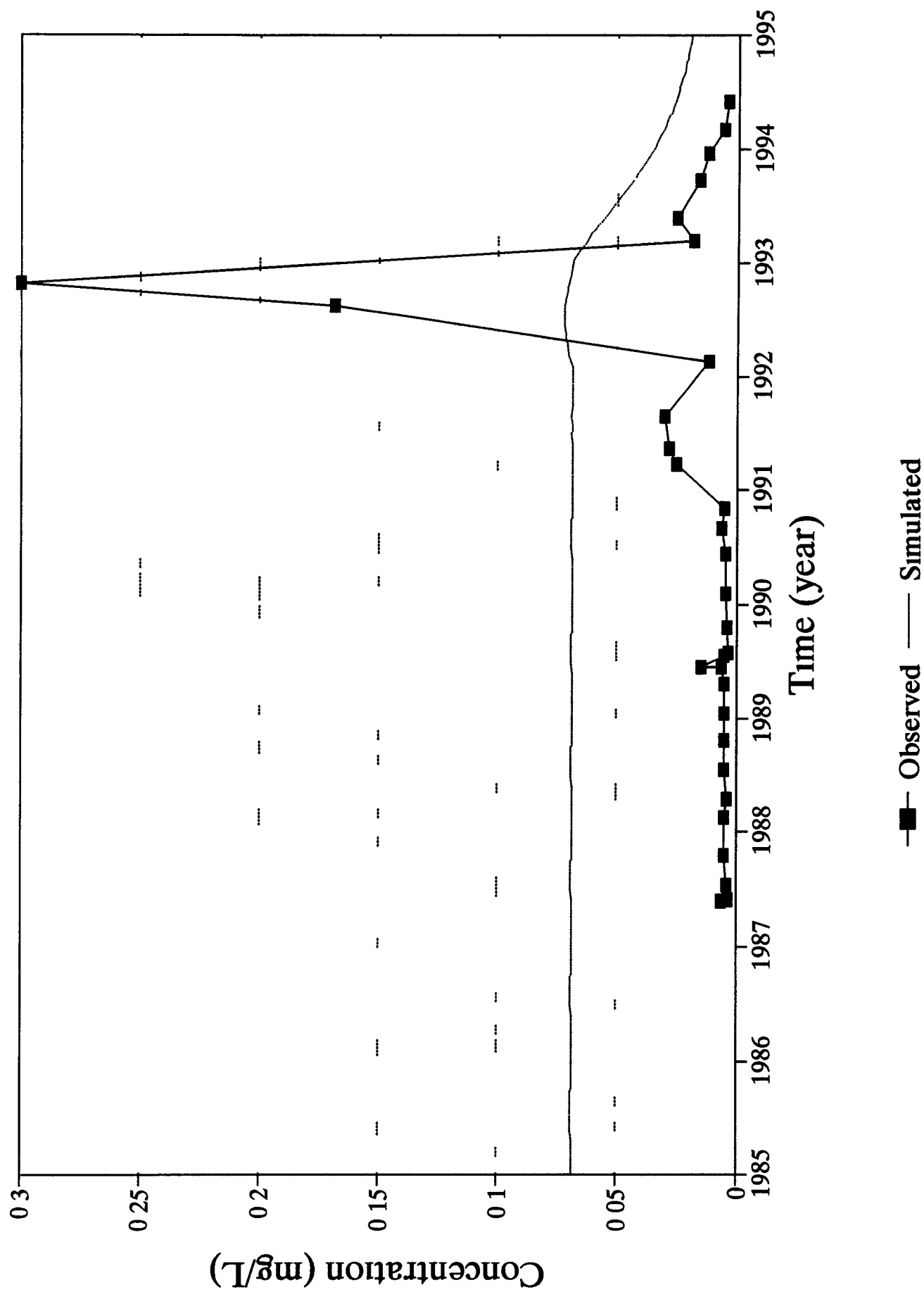


Figure B-27

1,1-DCE Calibration of Well 4387

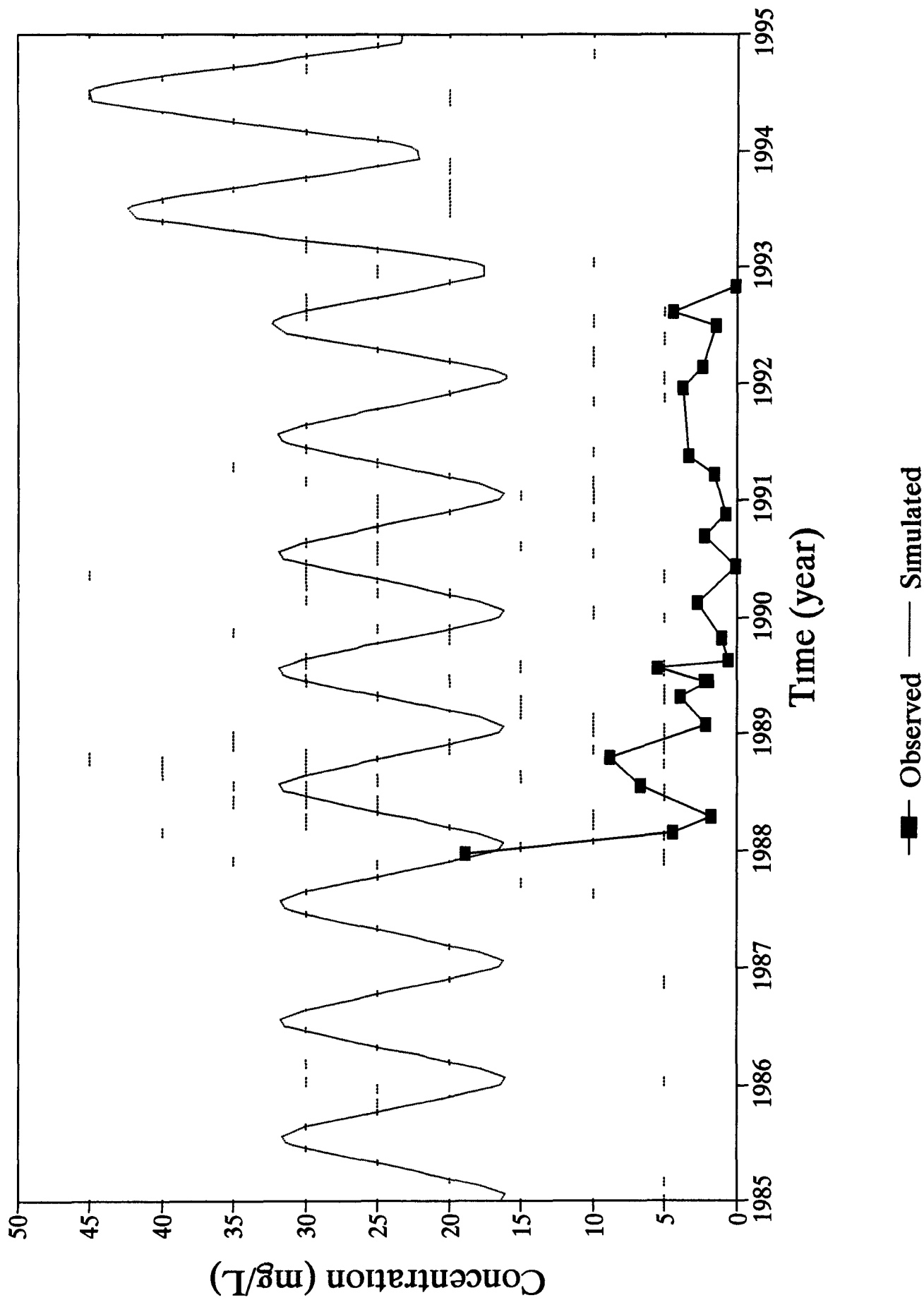


Figure B-28

CCL Calibration of Well 0487

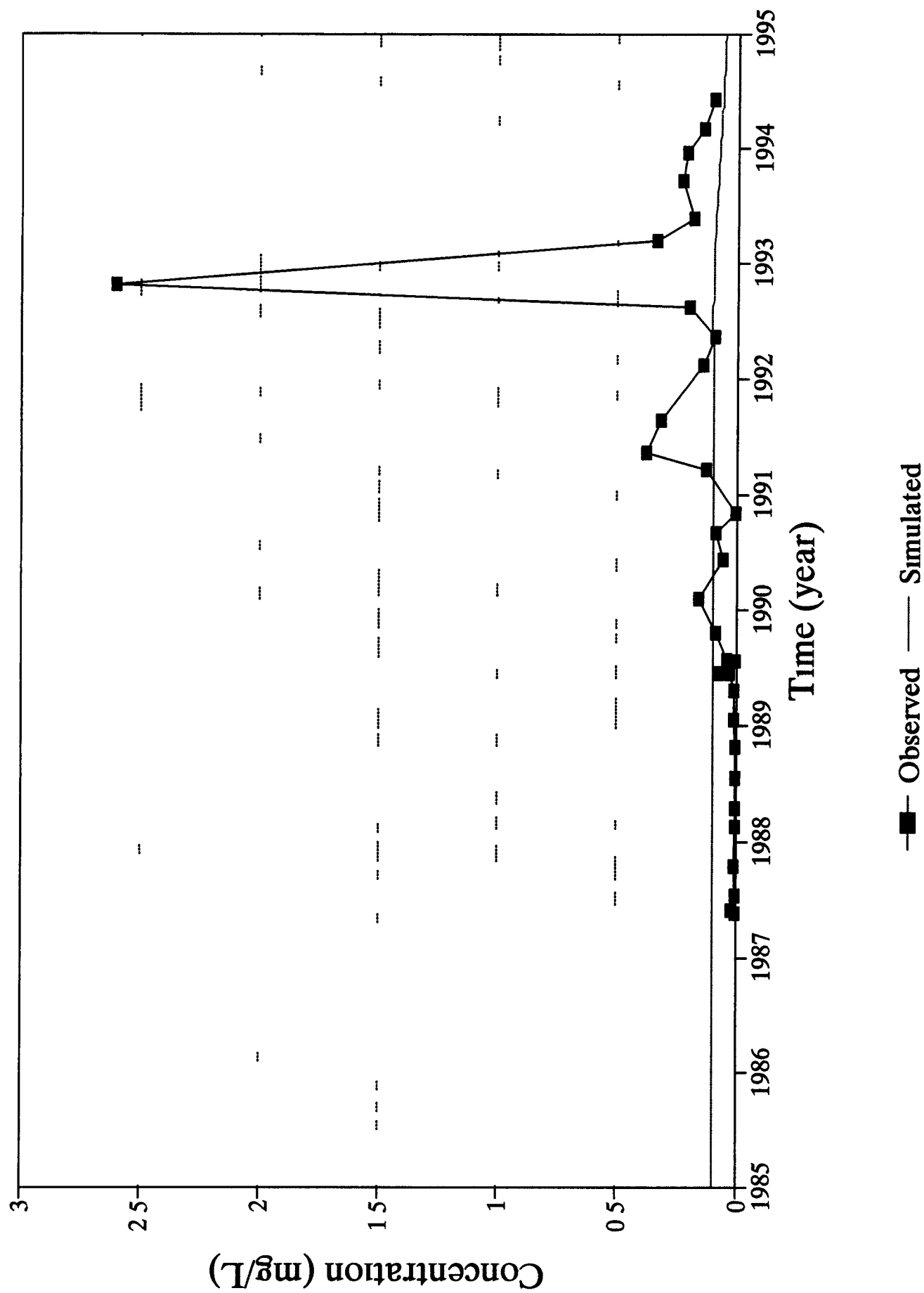
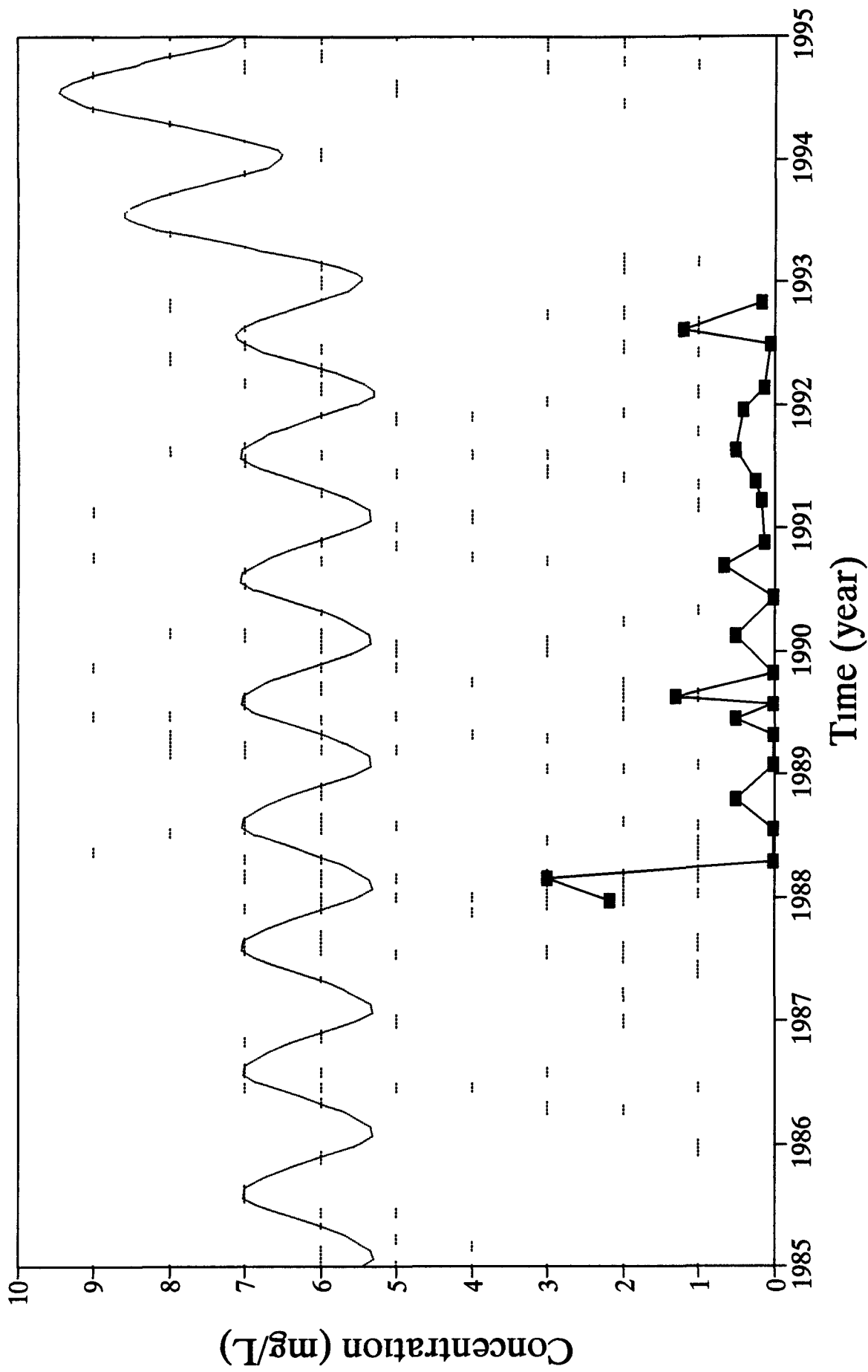


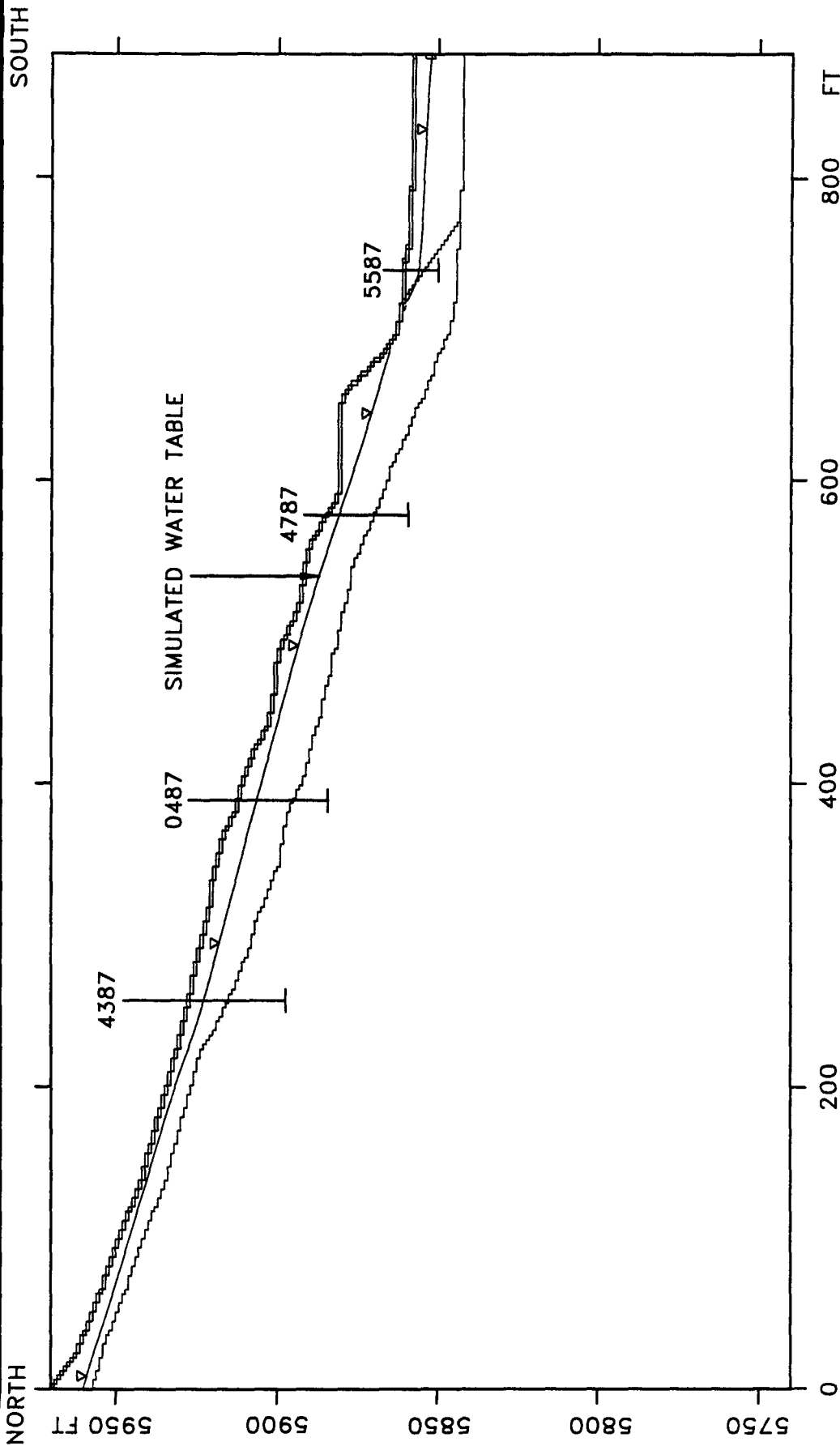
Figure B-29

CCL Calibration of Well 4387



—■— Observed — Simulated

Figure B-30

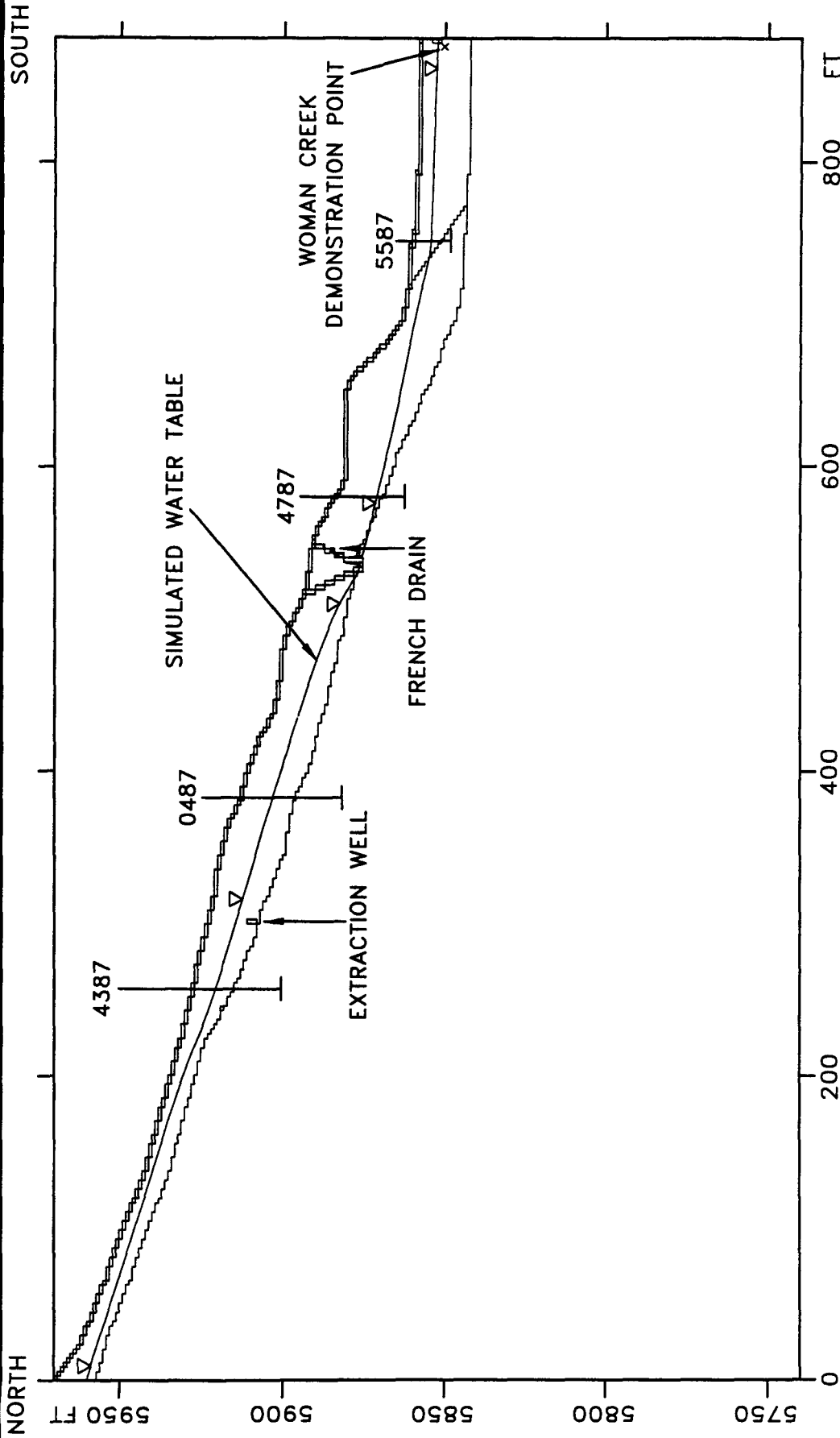


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Simulated Water Table
Steady State

Figure B-31

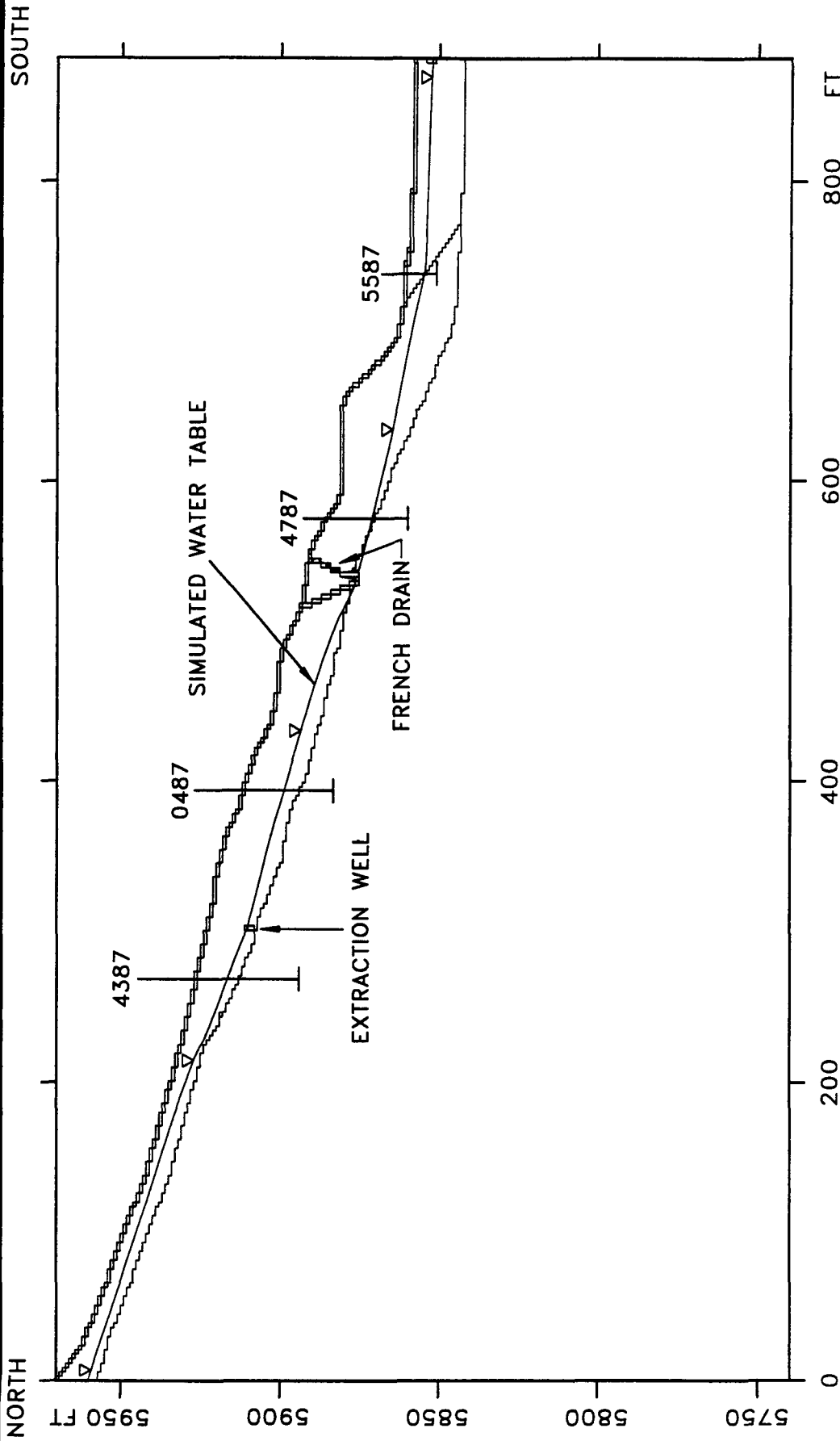


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Simulated Water Table
Time = 8766 Days (1993)

Figure B-32

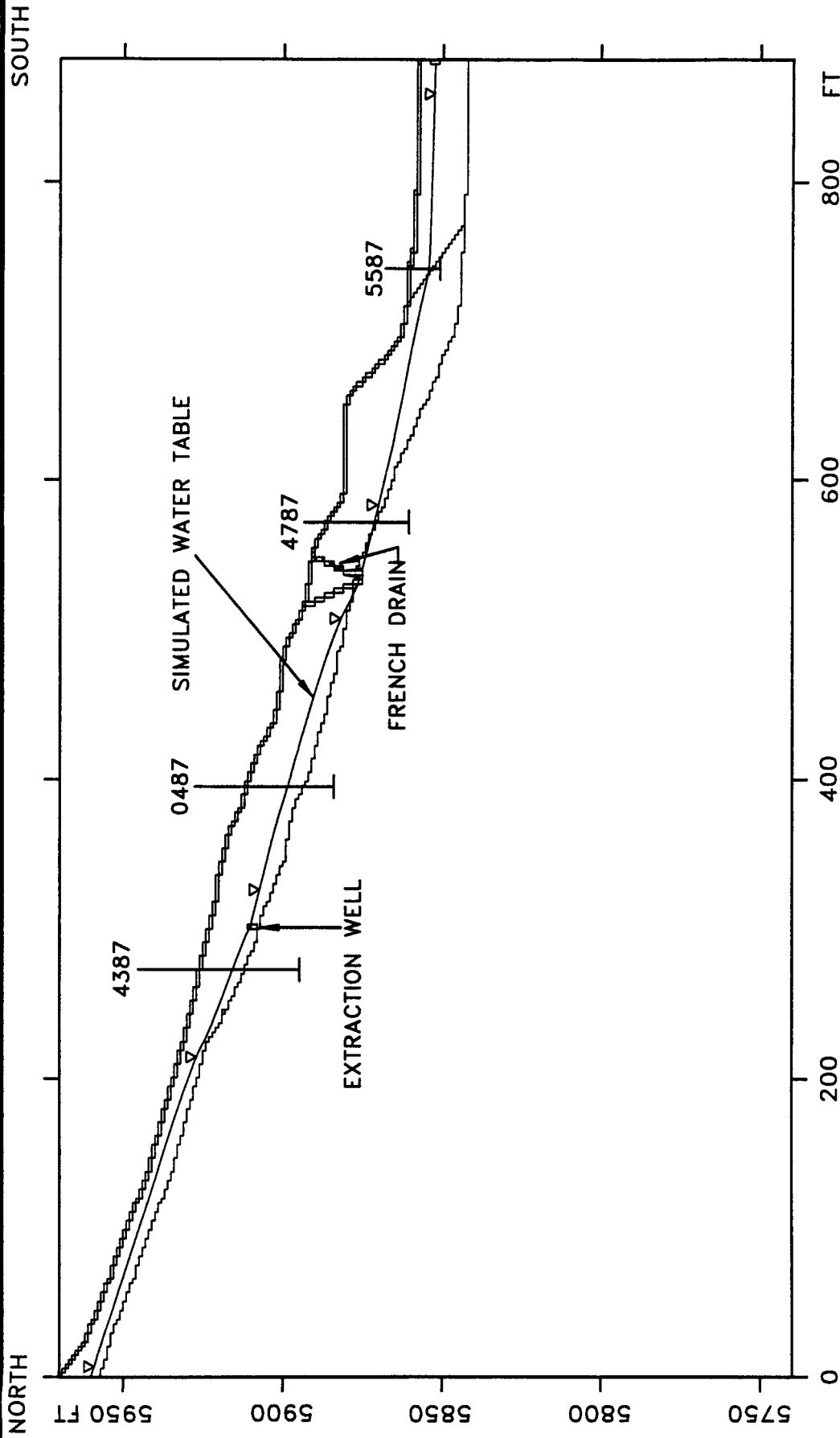


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Simulated Water Table
Time = 9855 Days (1996)

Figure B-33

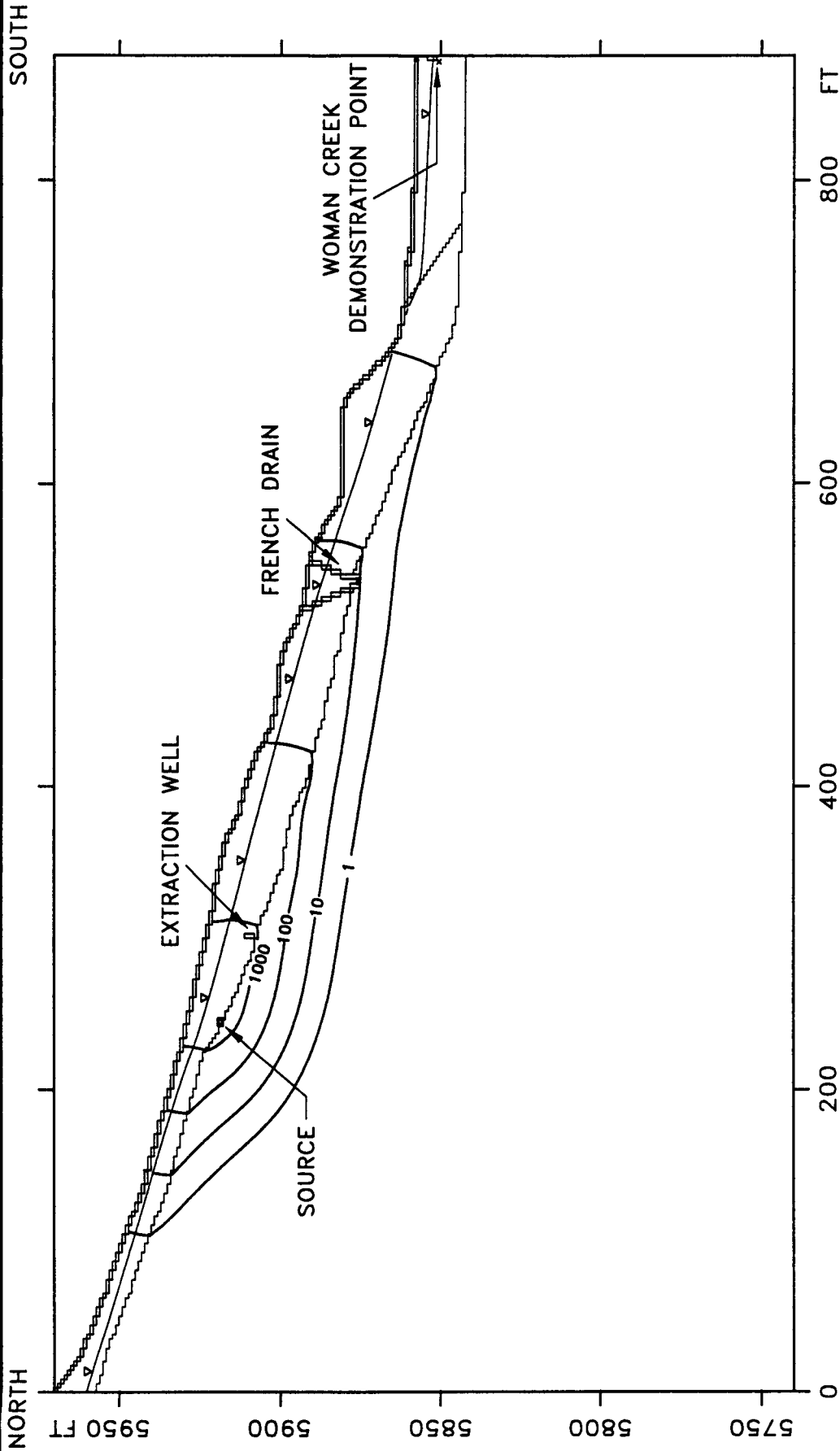


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Simulated Water Table
Time = 10585 Days (1998)

Figure B-34



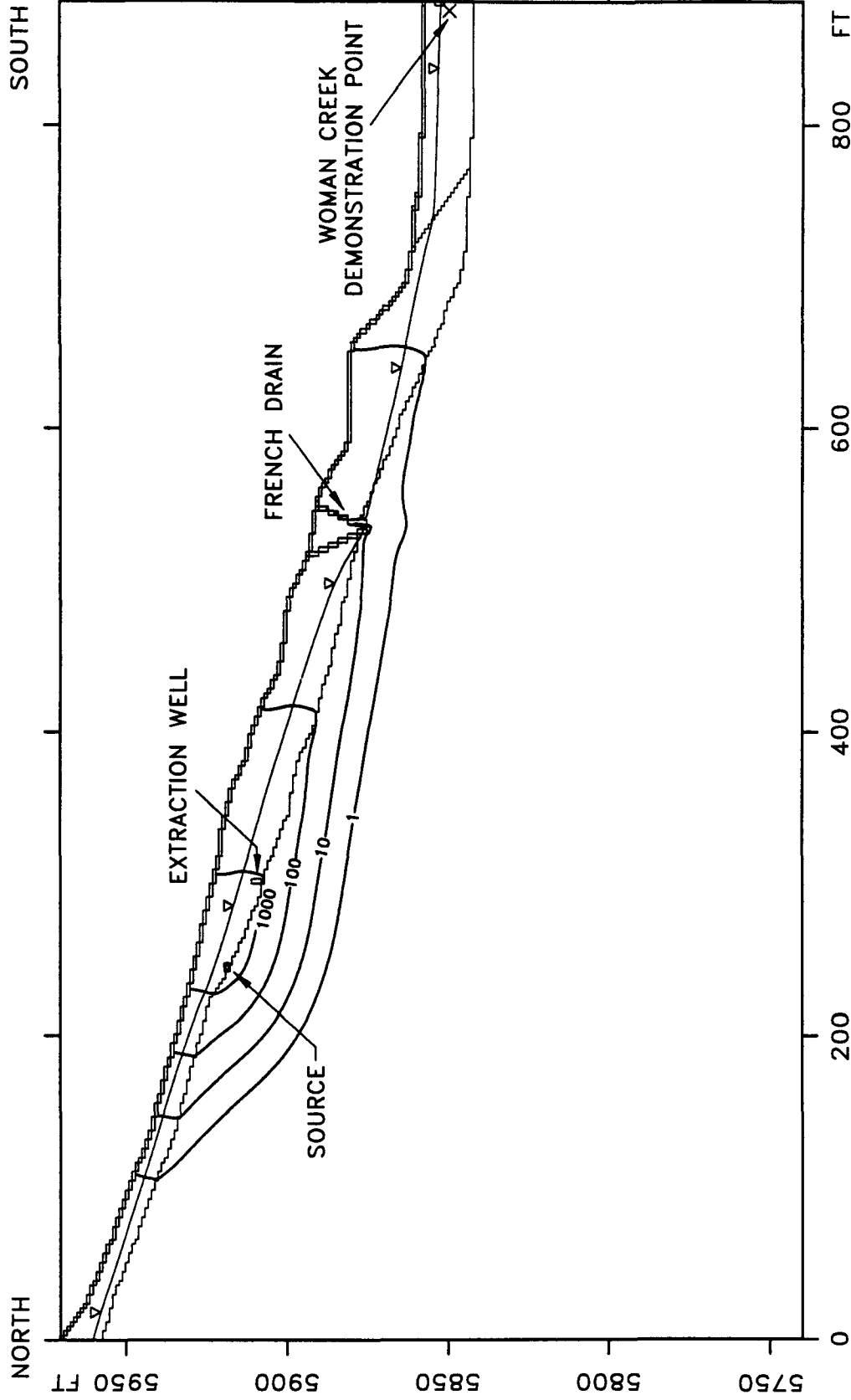
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Concentration Contours
Of PCE
Time = 8401 Days (1992)

Figure B-35

NOTE Concentrations in ppb

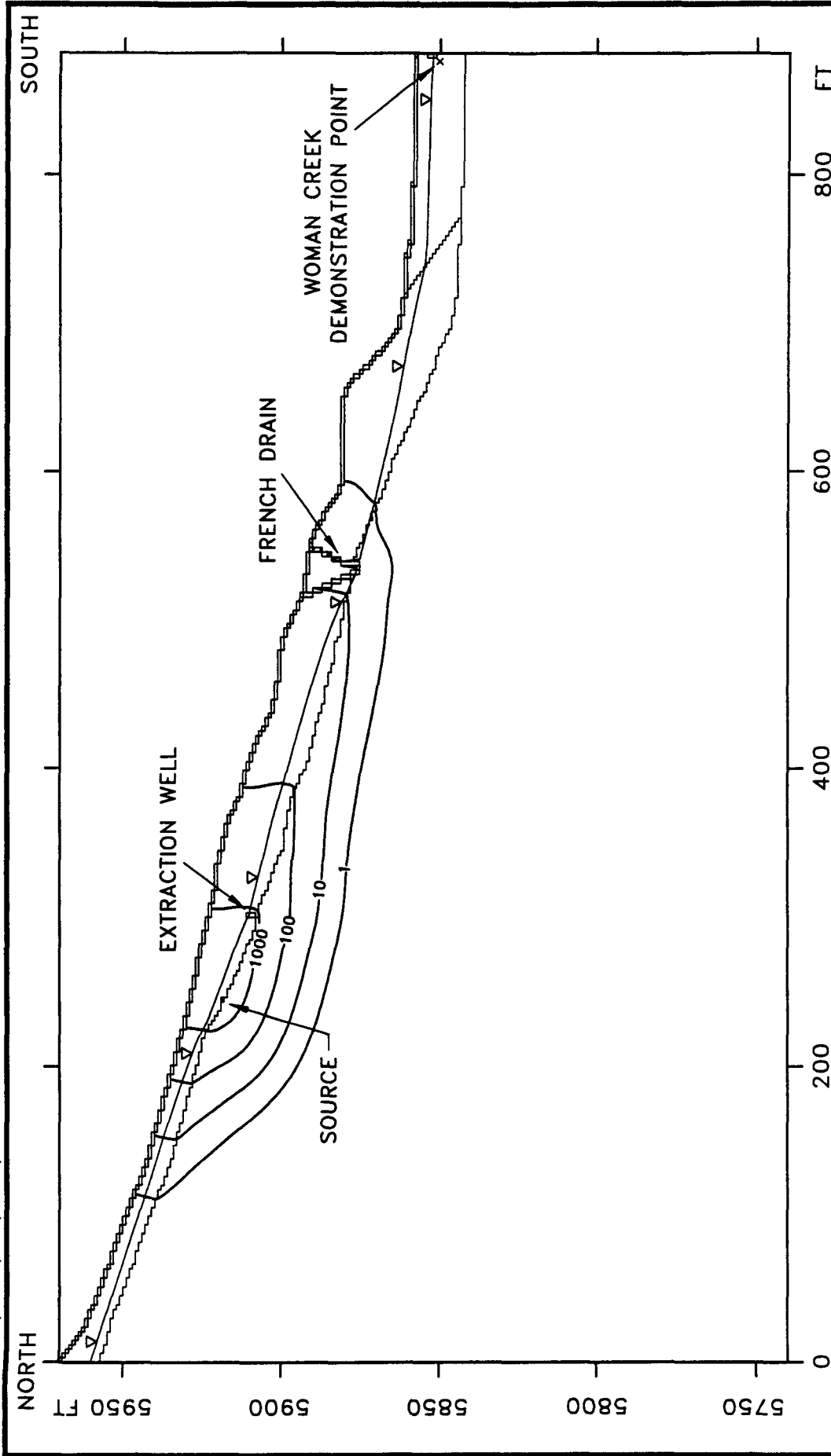


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Concentration Contours
Of PCE
Time = 8766 Days (1993)
Figure B-36

NOTE Concentrations in ppb



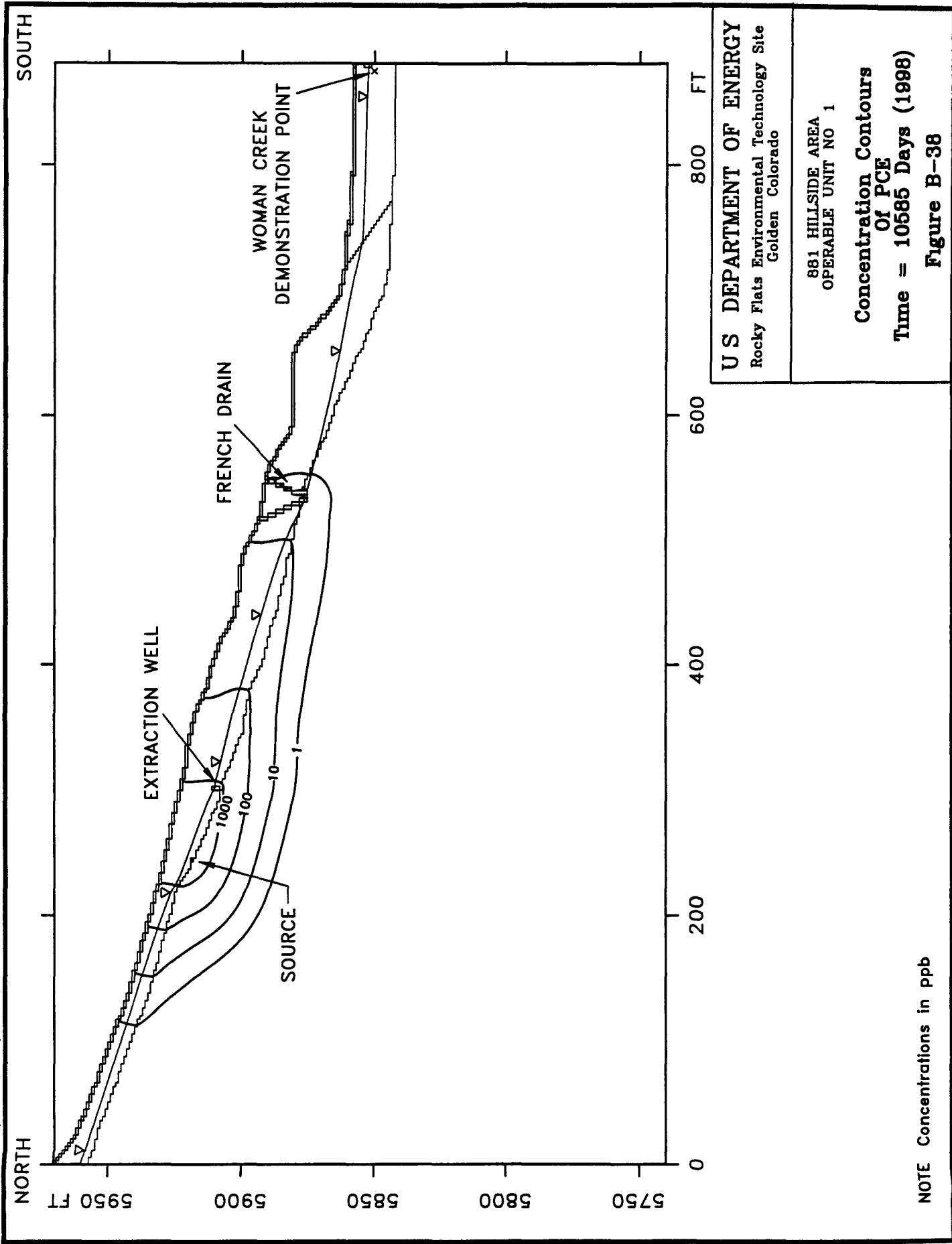
U S D E P A R T M E N T O F E N E R G Y
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Golden Colorado

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OPERABLE UNIT NO 1

Concentration Contours
Of PCE
Time = 9855 Days (1996)

Figure B-37

NOTE Concentrations in ppb



Sensitivity Analysis - Kd Down Gradient of the French Drain

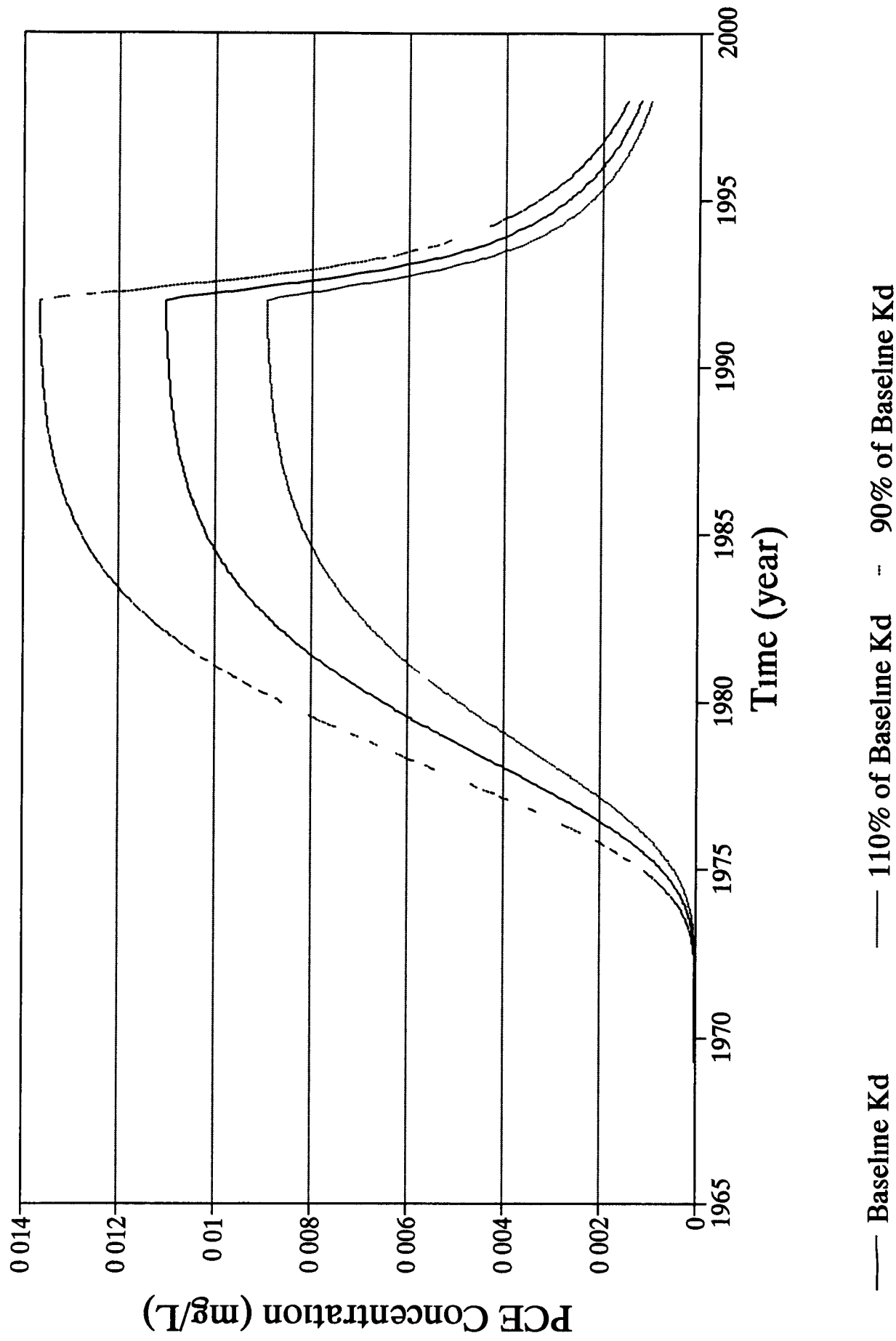
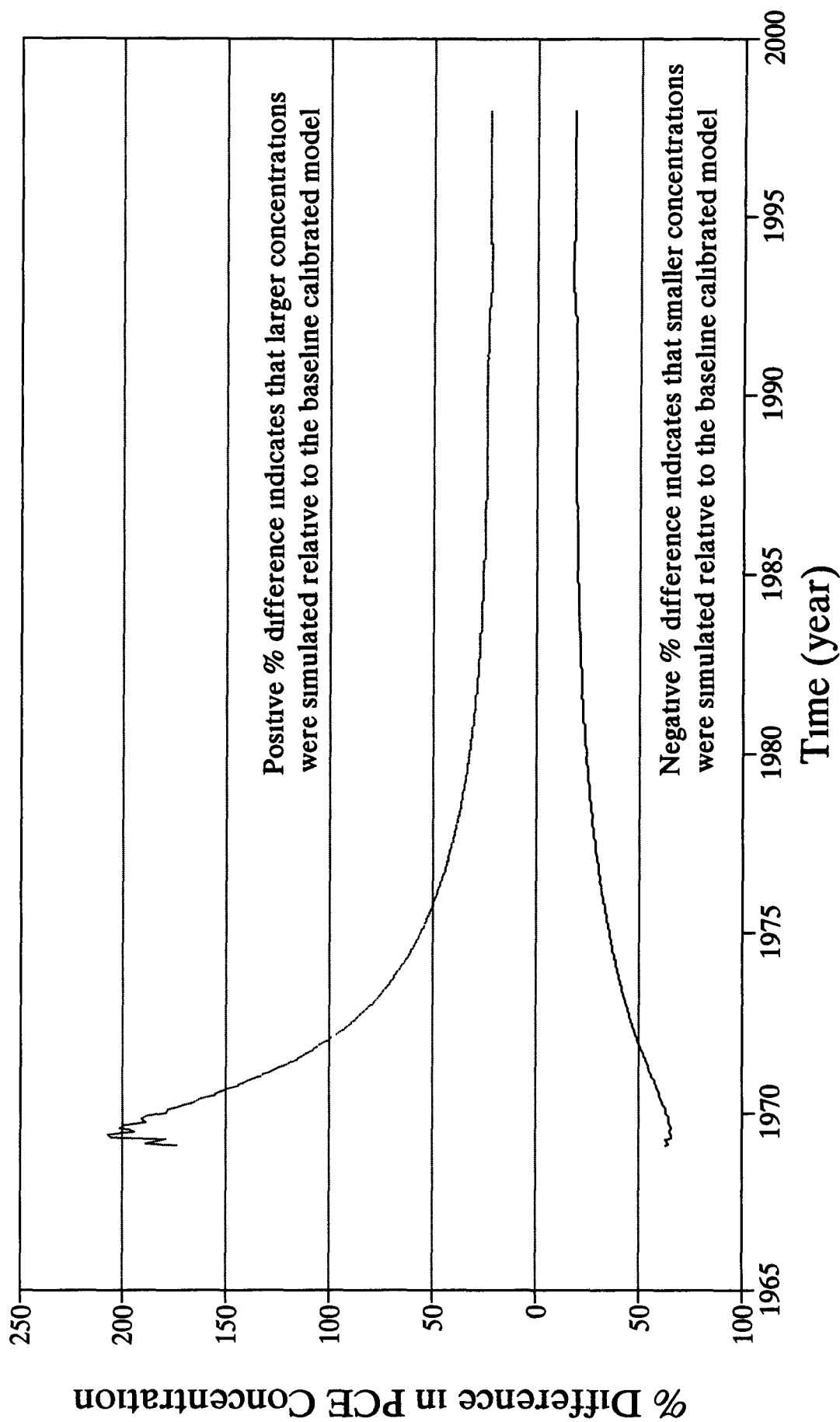


Figure B-39

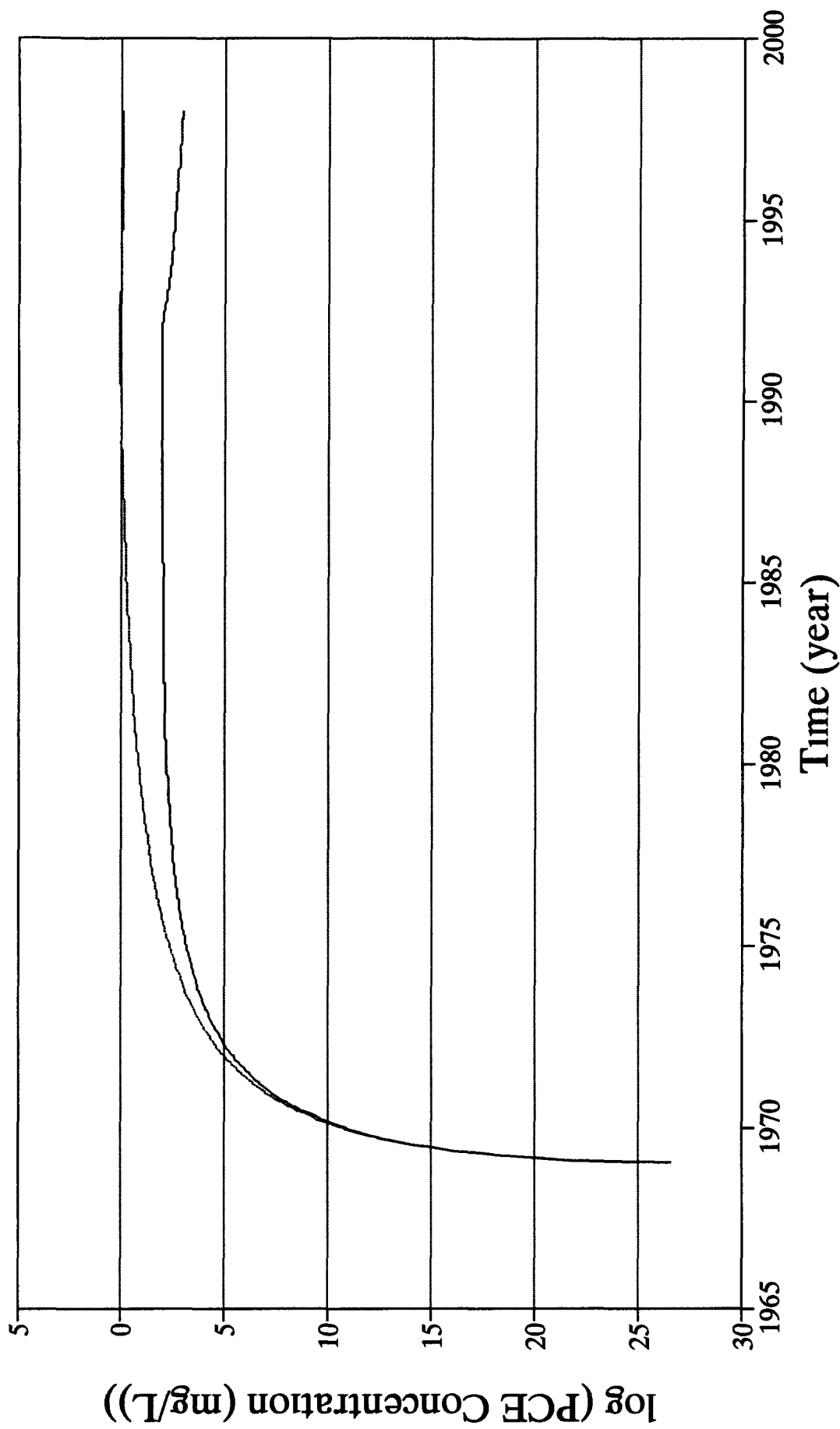
Sensitivity Analysis - Kd Down Gradient of the French Drain



— 110% of Baseline Kd — 90% of Baseline Kd

Figure B-40

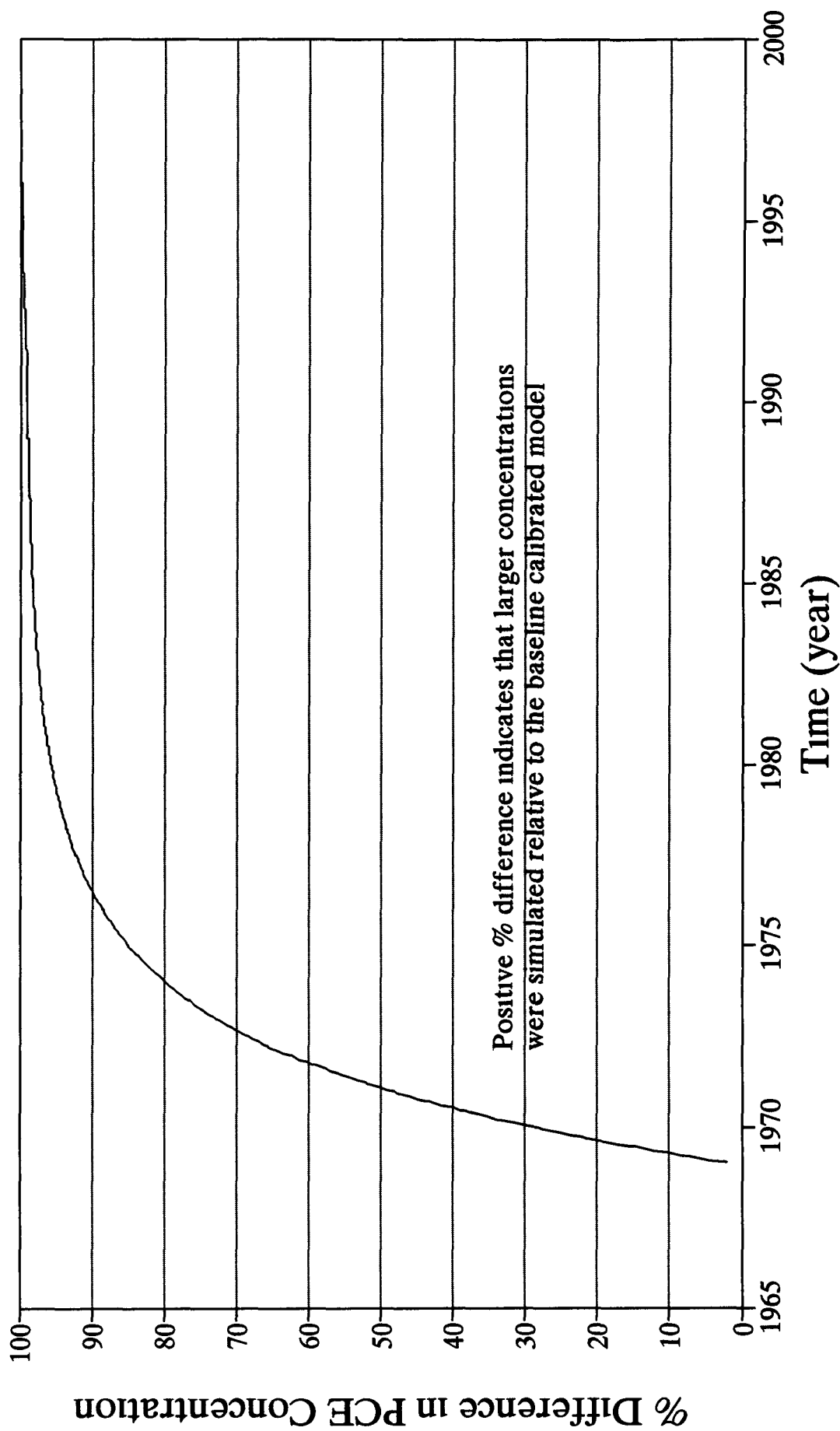
Sensitivity Analysis - Decay Down Gradient of the French Drain



— Baseline Decay — No Decay

Figure B 41

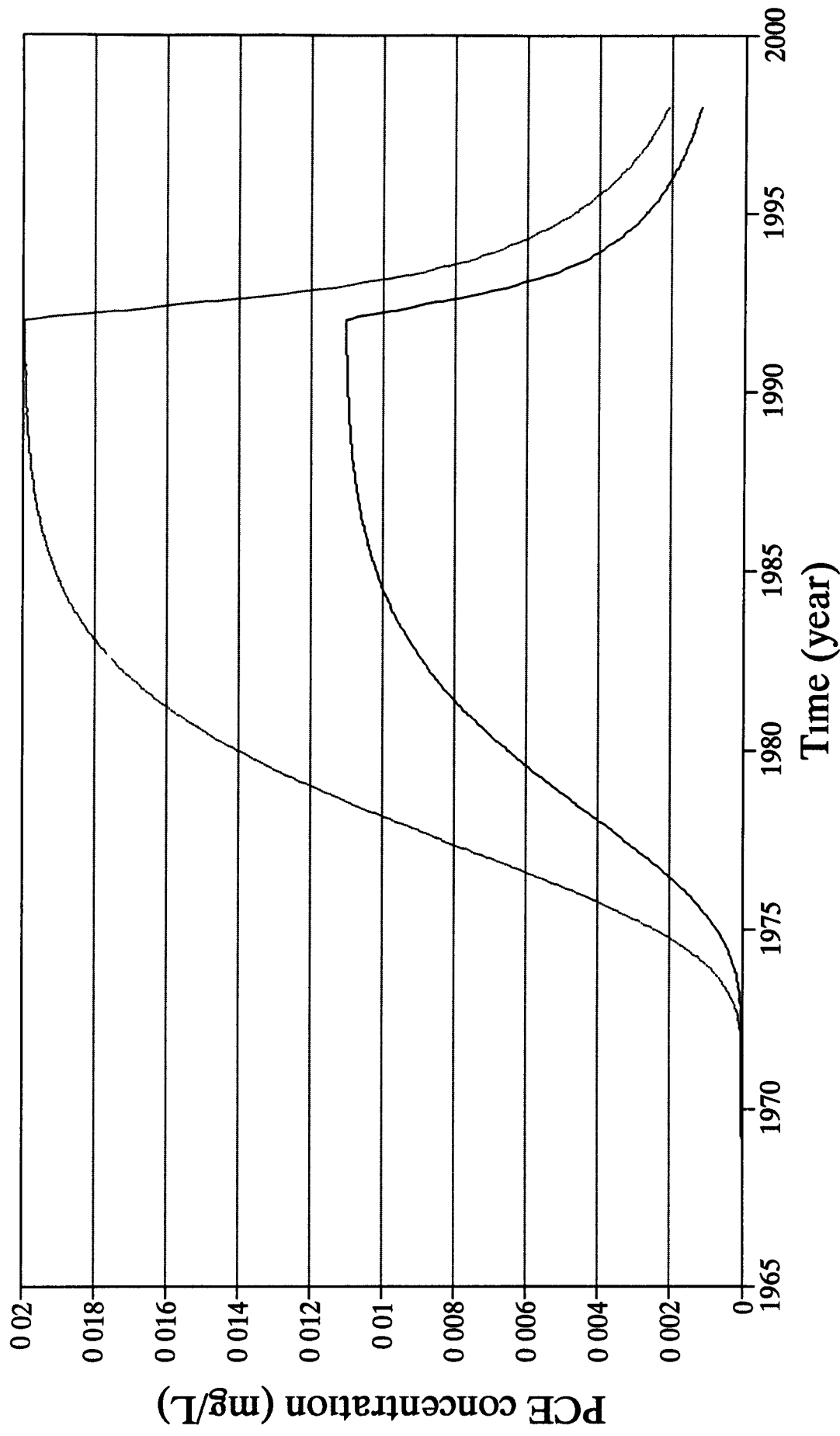
Sensitivity Analysis - Decay Down Gradient of the French Drain



— No Decay

Figure B 42

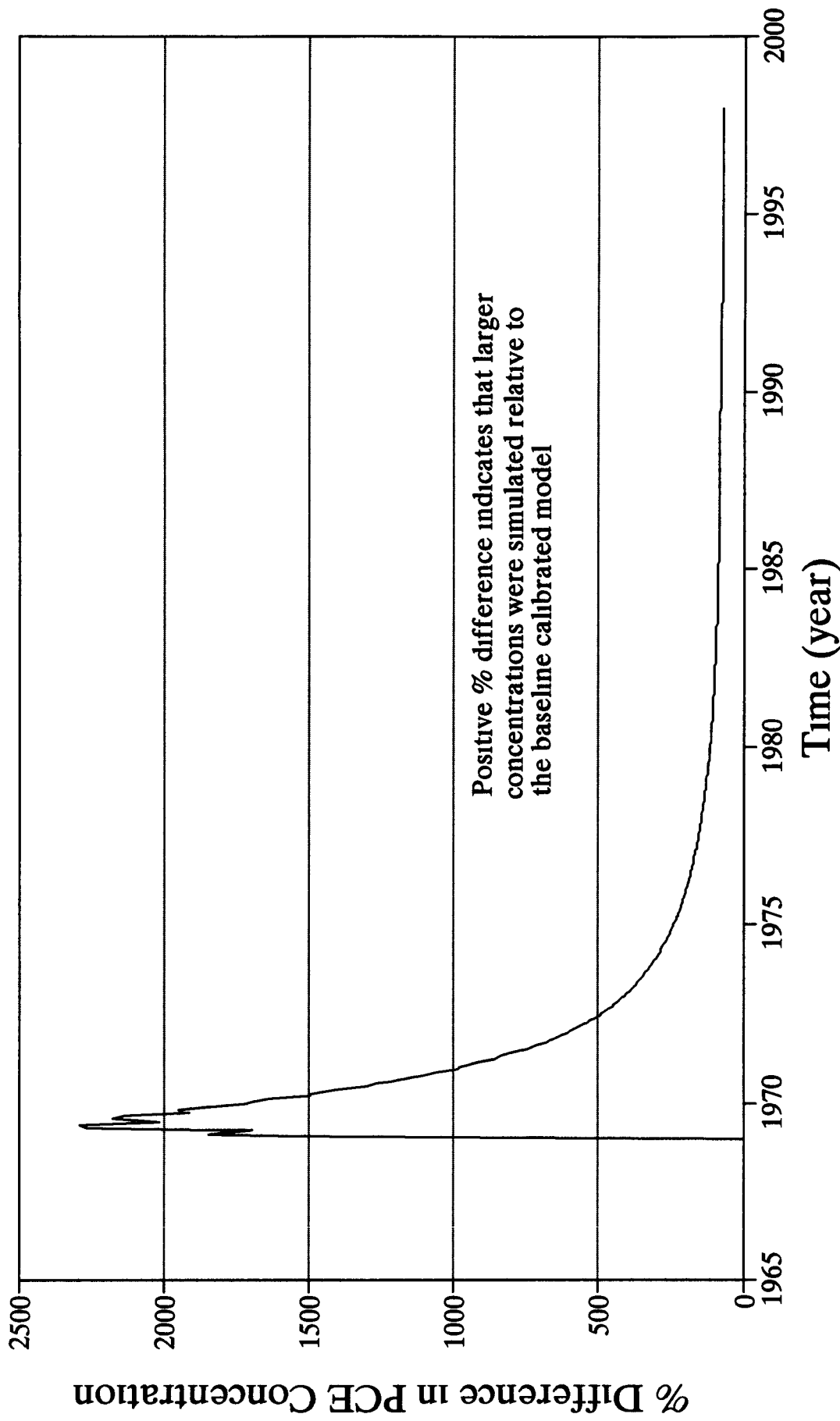
Sensitivity Analysis - Porosity Down Gradient of the French Drain



— Baseline Porosity — 5 x Baseline Por

Figure B-43

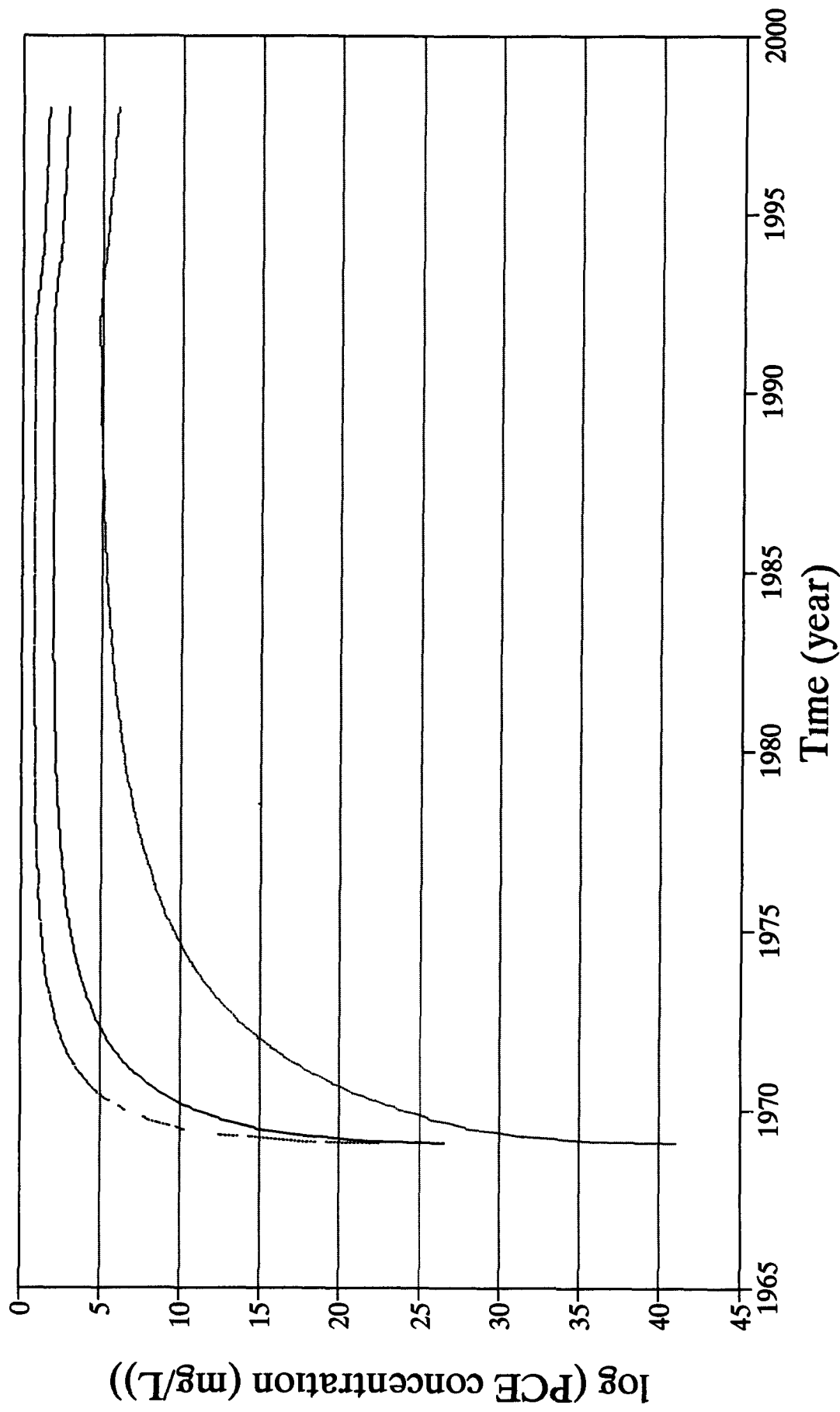
Sensitivity Analysis - Porosity Down Gradient of the French Drain



— 5 x Baseline Por

Figure B-44

Sensitivity Analysis - Hydraulic Cond Down Gradient of the French Drain

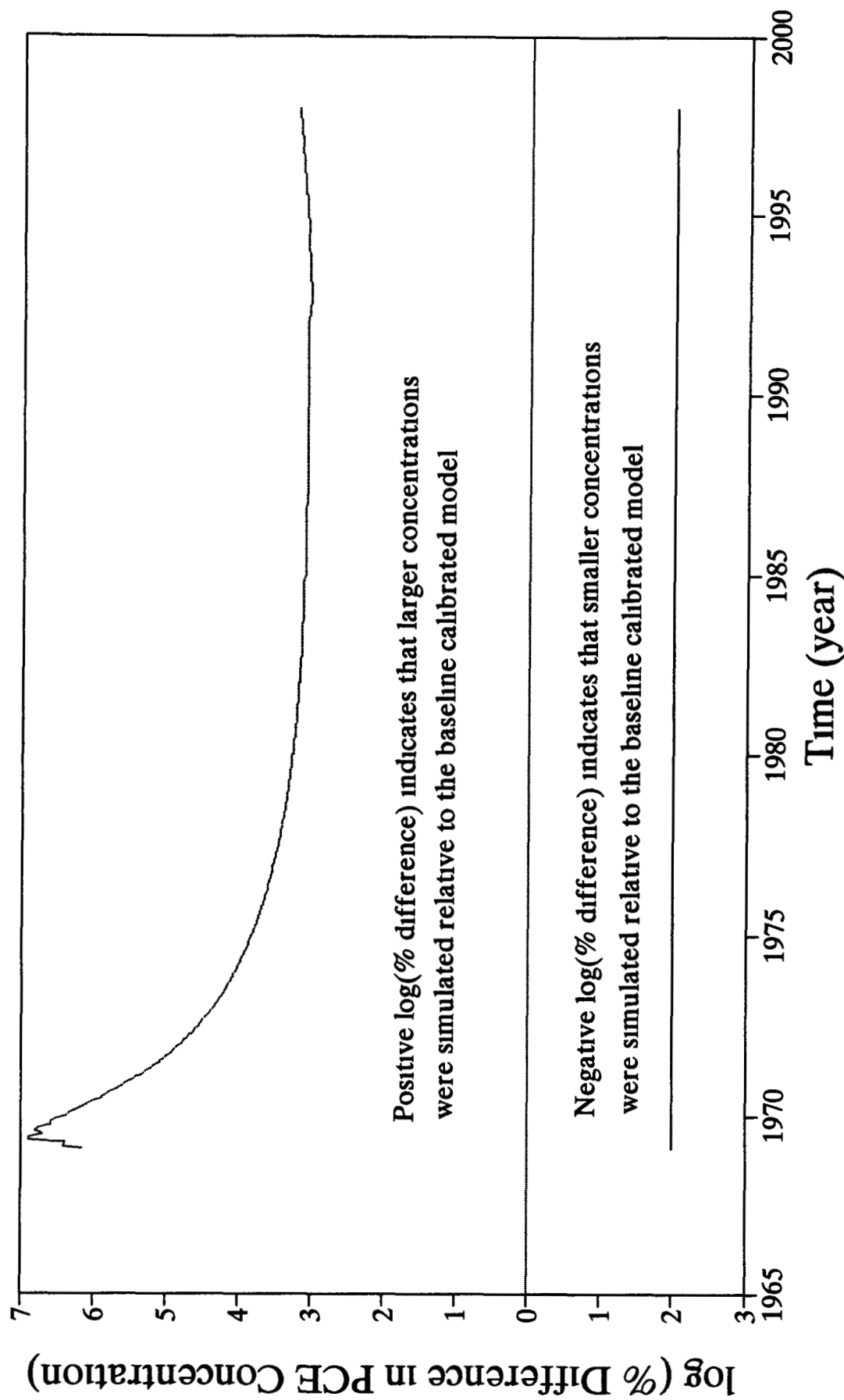


— Baseline Kxx — Lower Kxx - - - Higher Kxx

* See Table B 3

Figure B 45

Sensitivity Analysis - Hydraulic Cond Down Gradient of the French Drain



— Lower Kxx — Higher Kxx

* See Table B 3

Figure B-46

No Action Alternative
Down Gradient of the French Drain

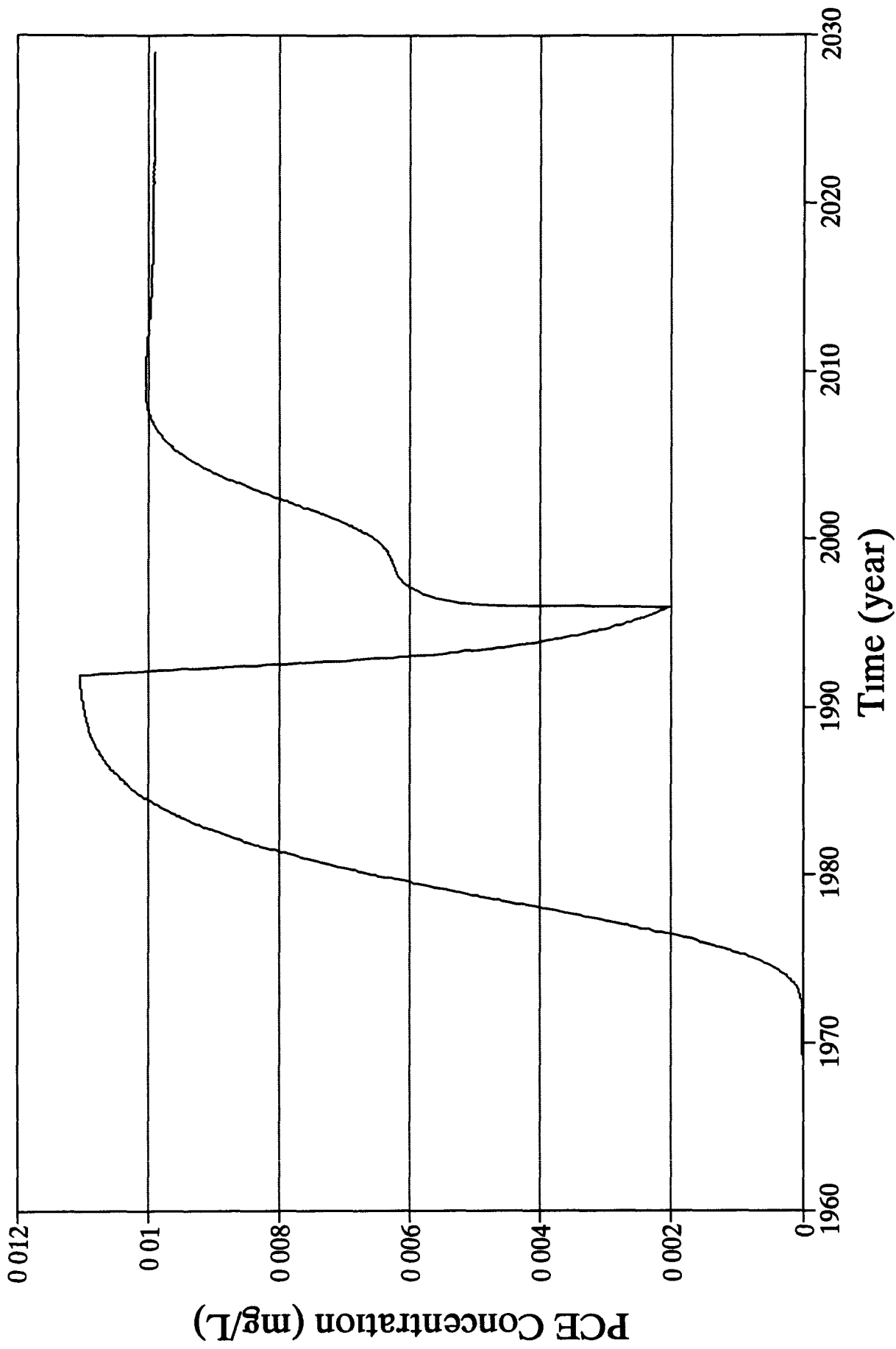


Figure B-47

No Action Alternative Woman Creek

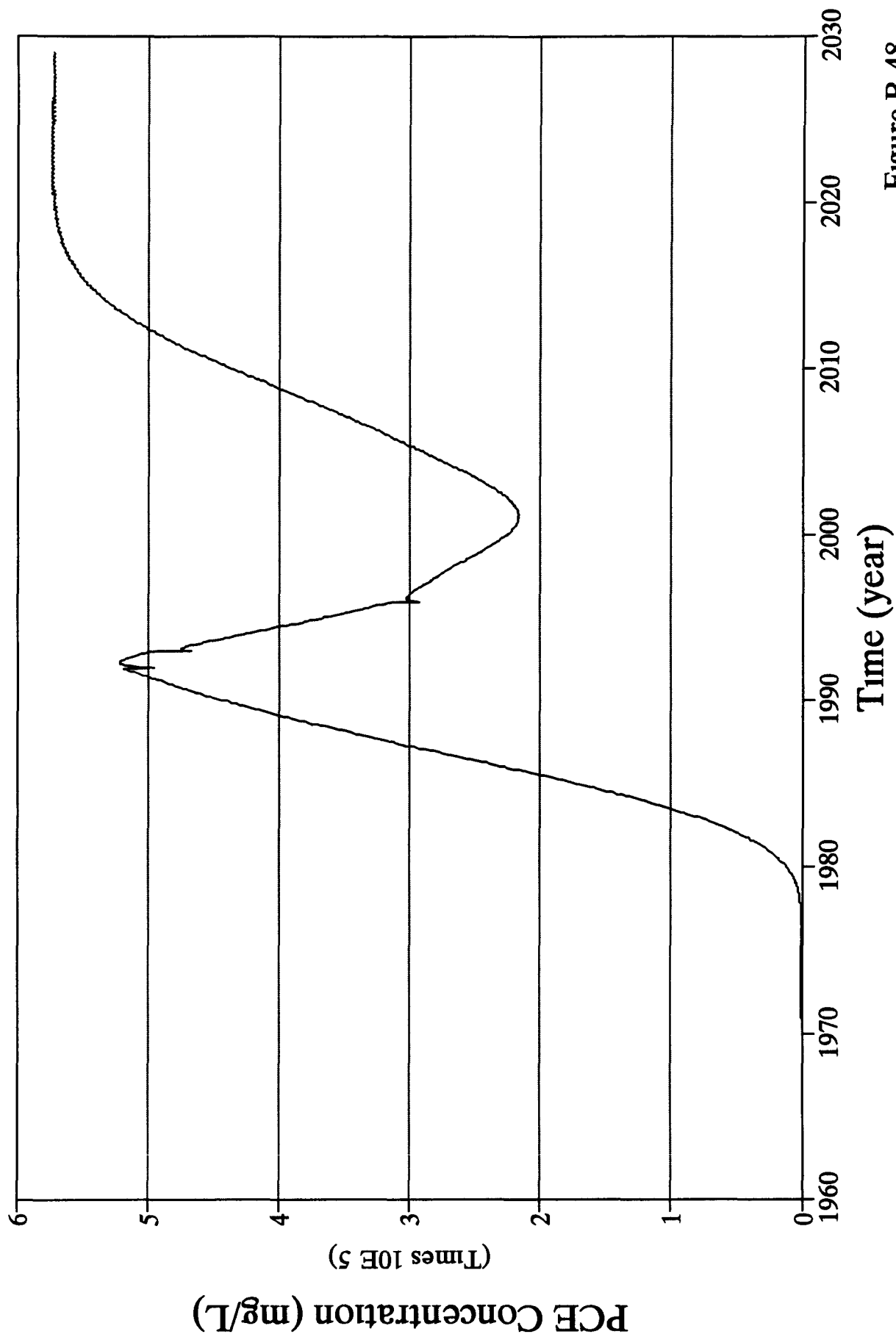


Figure B-48

No Action Alternative
Down Gradient of the French Drain

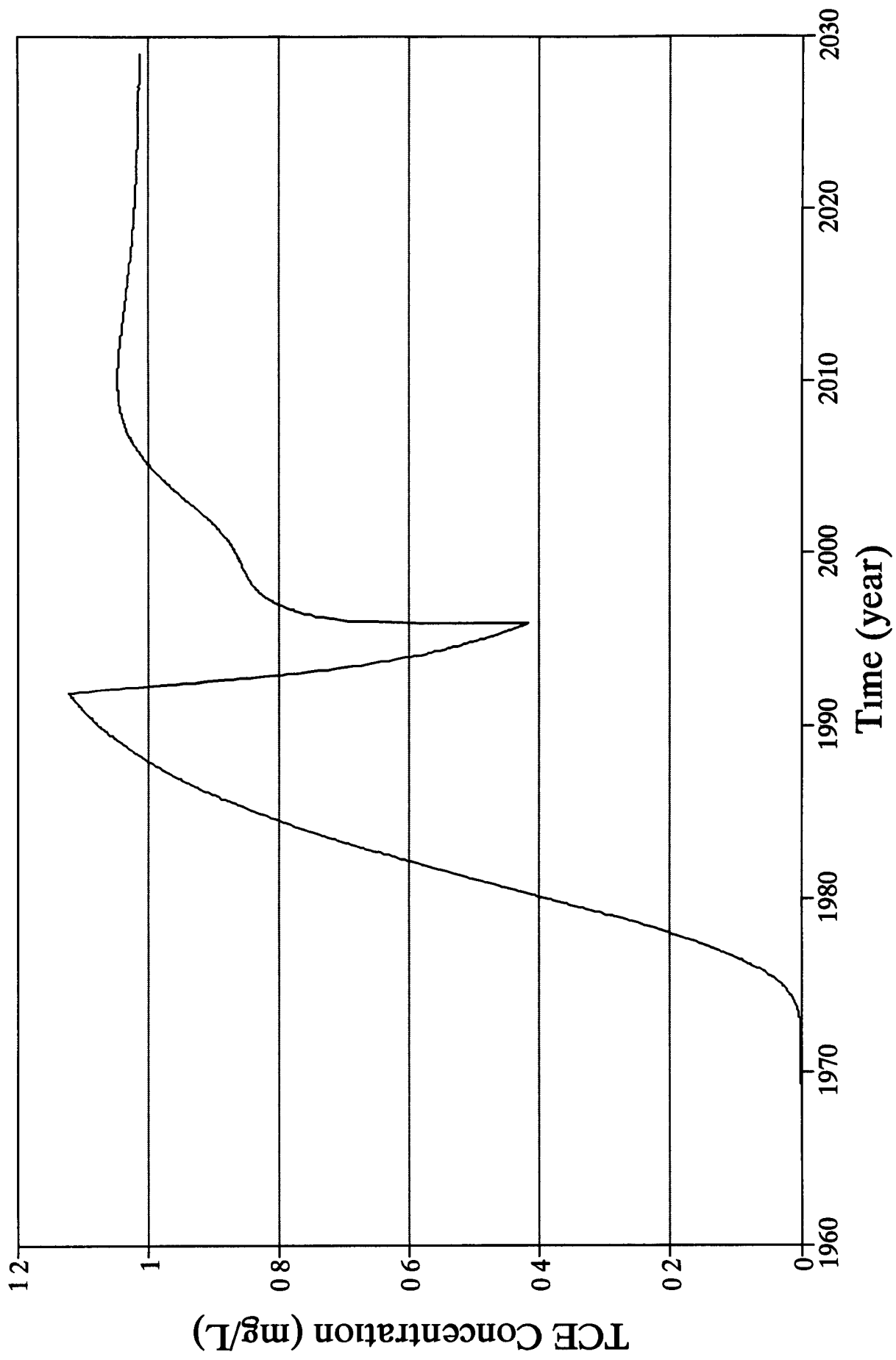


Figure B-49

No Action Alternative Woman Creek

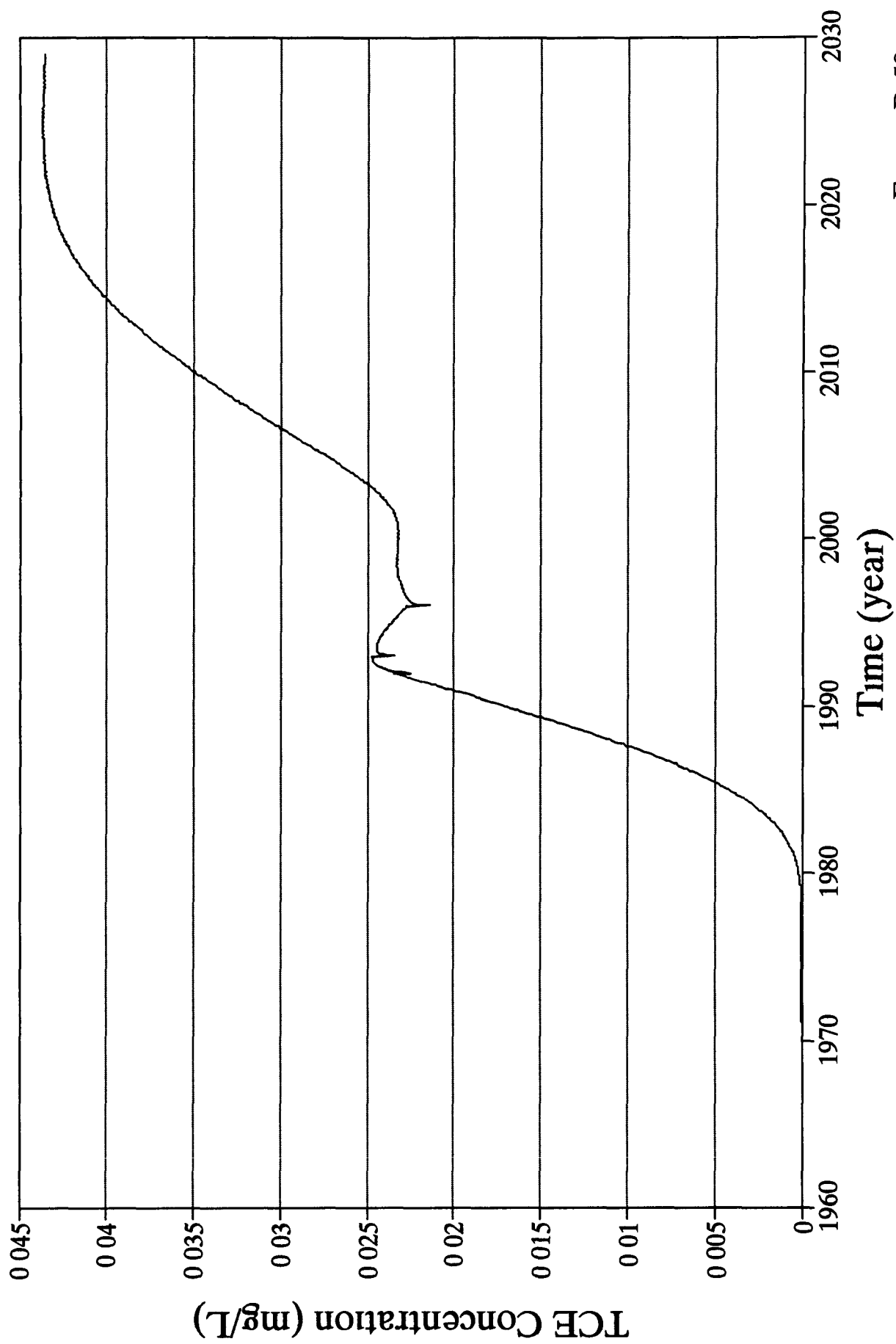


Figure B 50

No Action Alternative Down Gradient of the French Drain

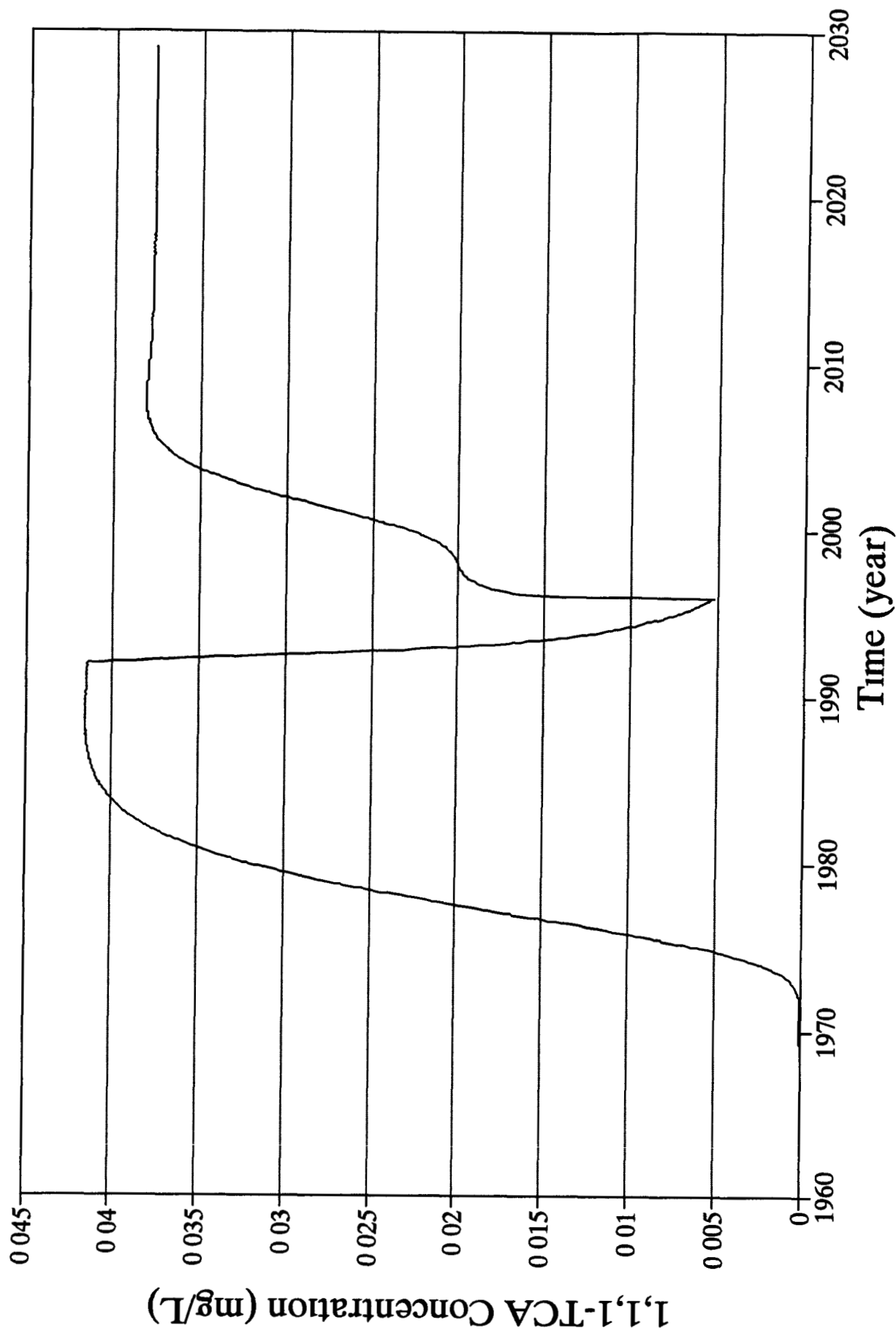


Figure B-51

No Action Alternative Woman Creek

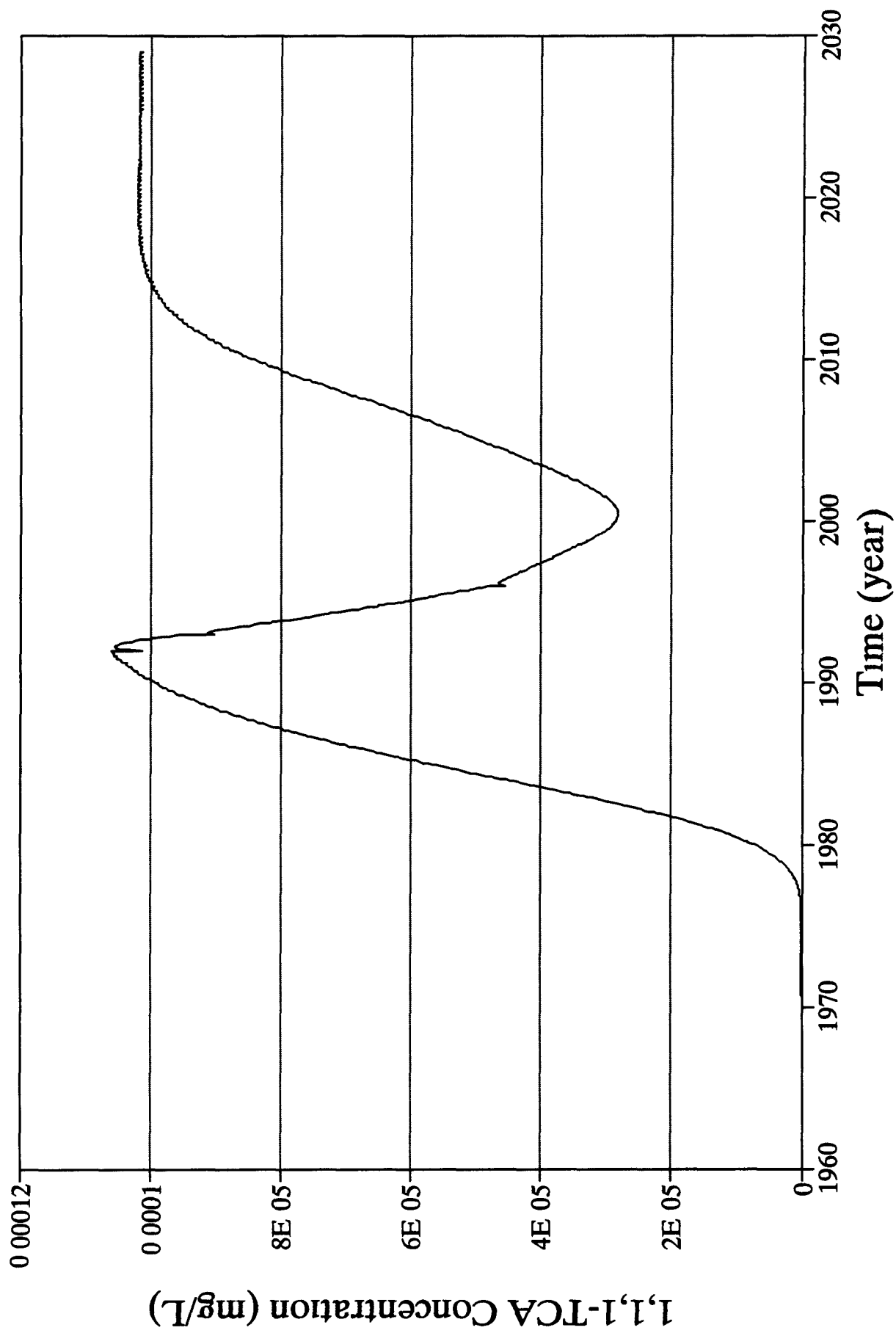


Figure B-52

No Action Alternative
Down Gradient of the French Drain

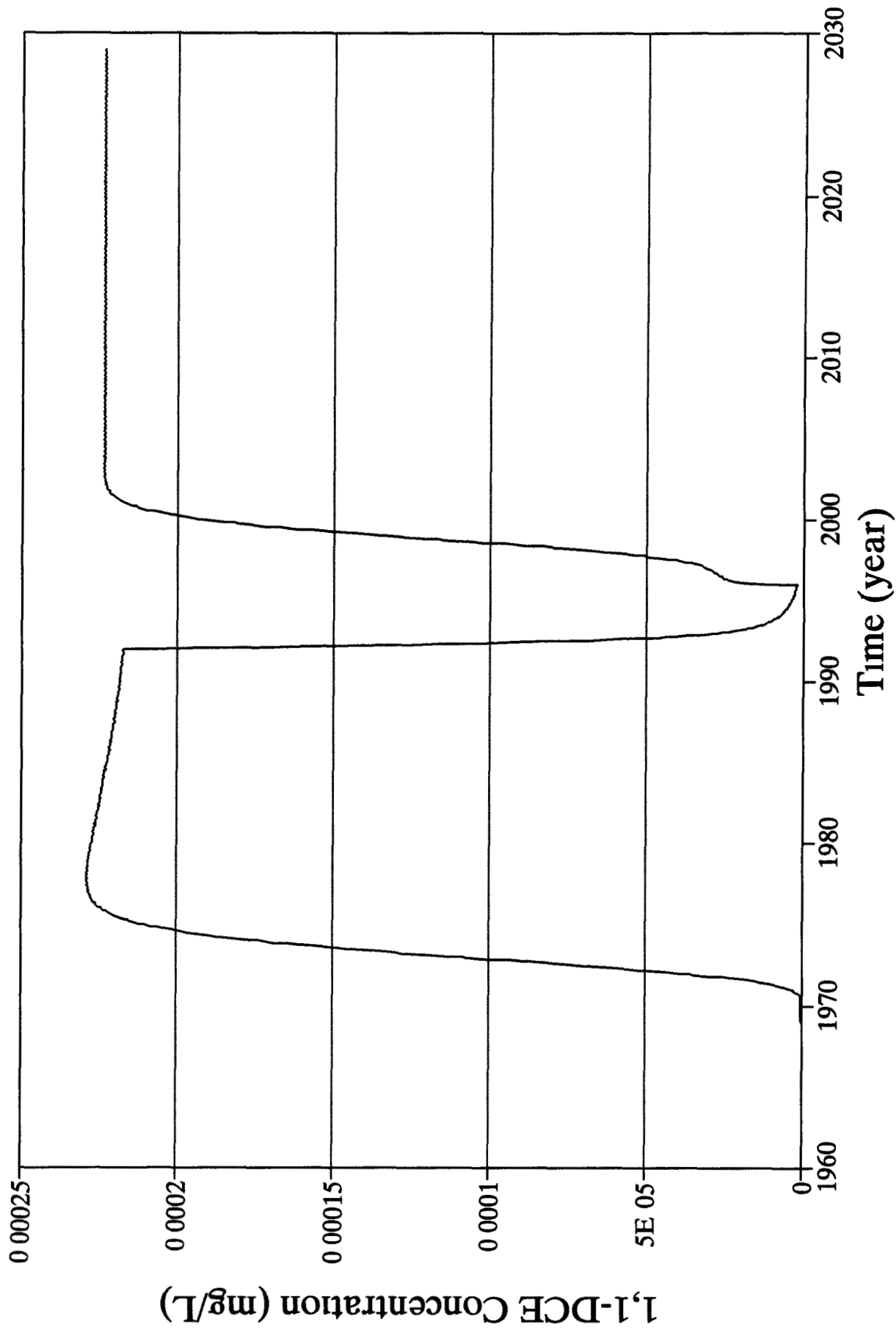


Figure B-53

No Action Alternative Woman Creek

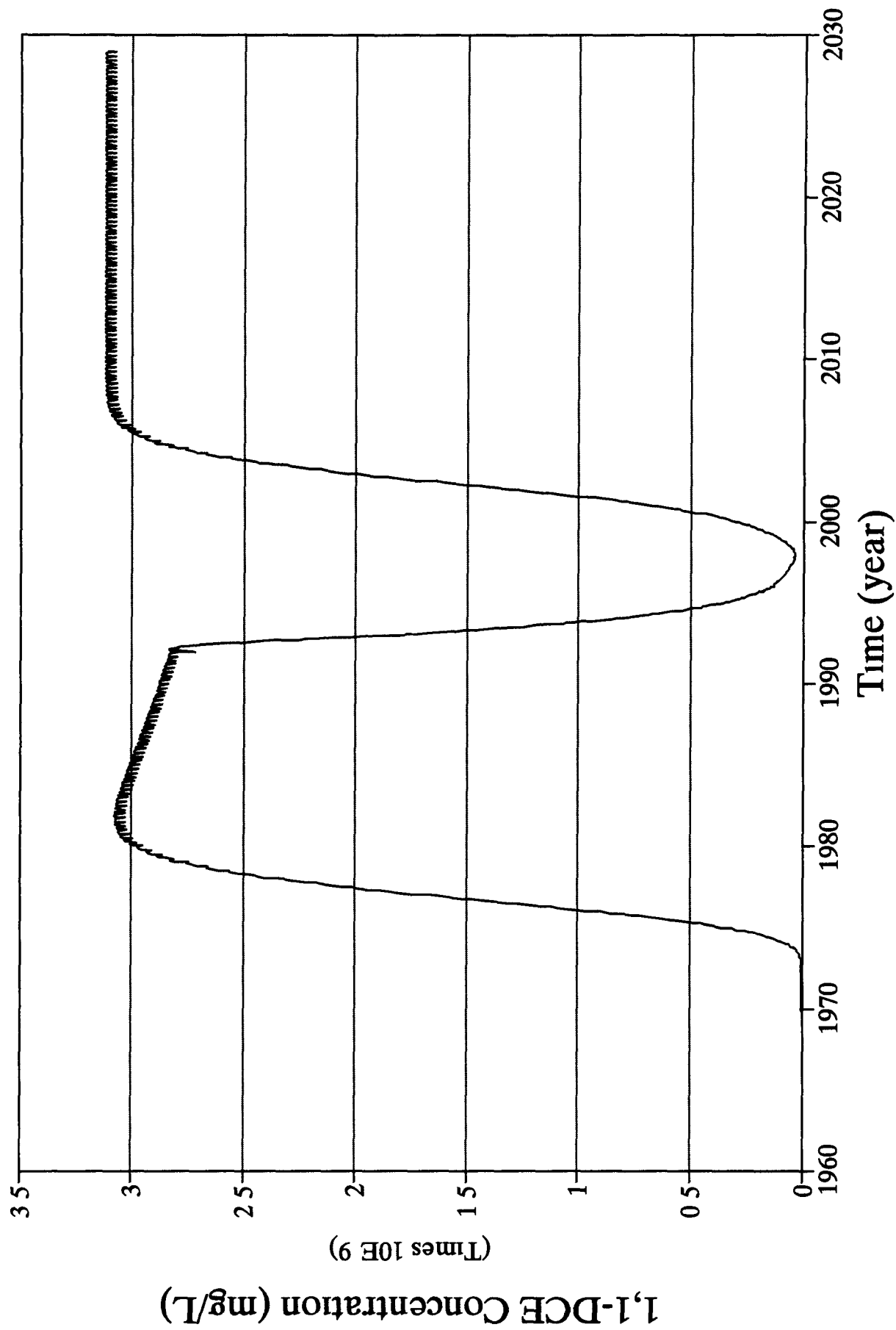


Figure B-54

No Action Alternative Down Gradient of the French Drain

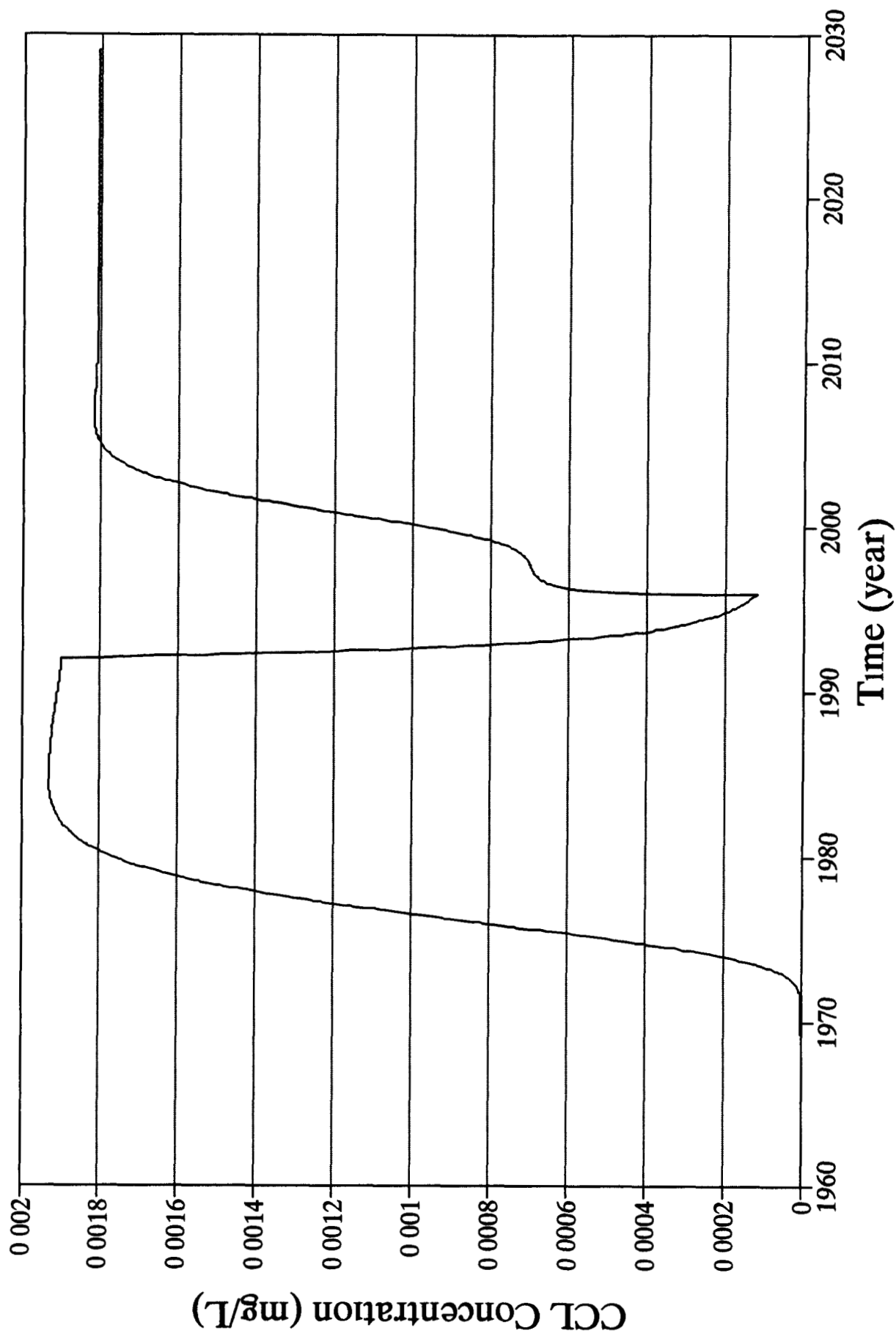


Figure B-55

No Action Alternative
Woman Creek

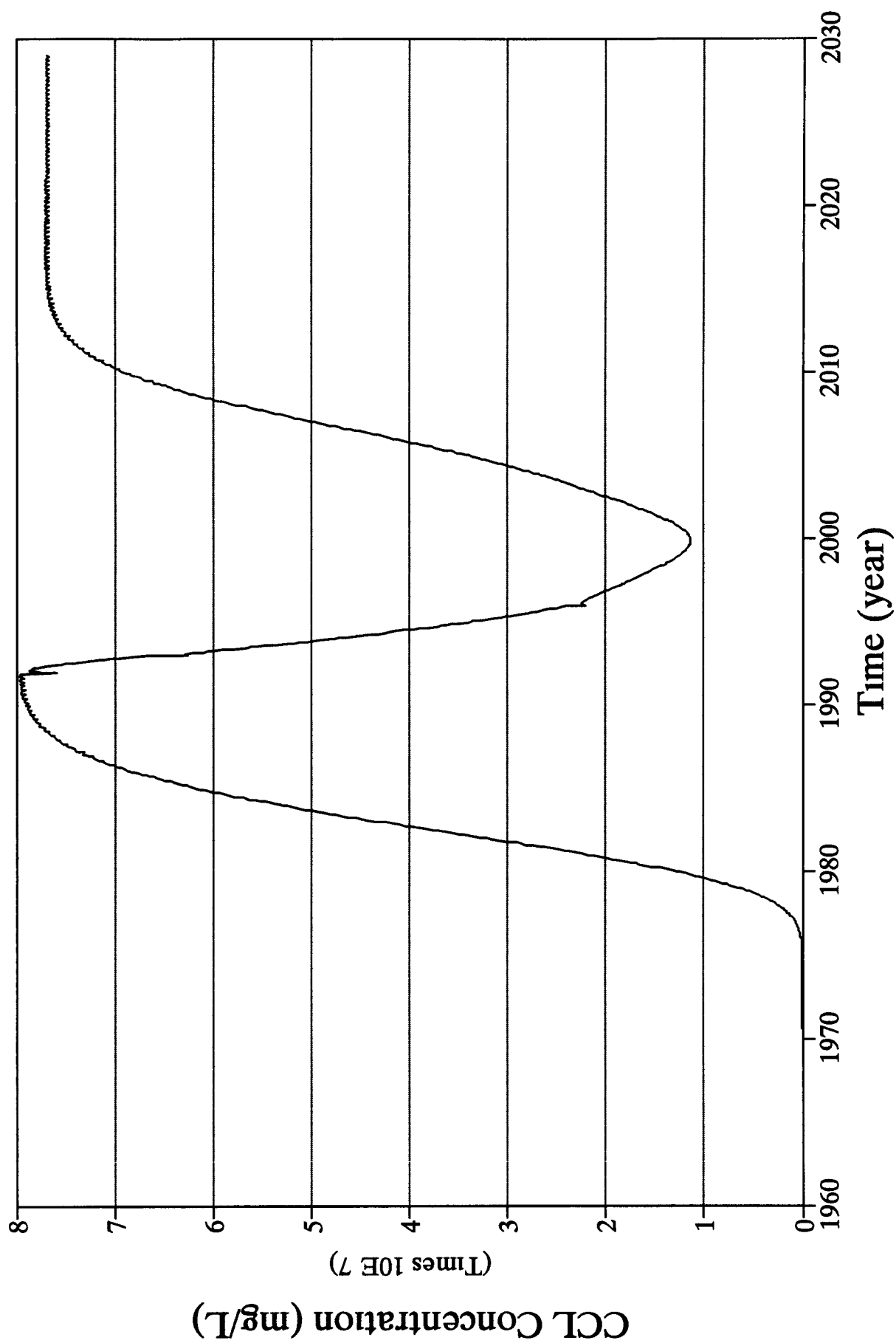


Figure B 56

Institutional Control Alternative Down Gradient of the French Drain

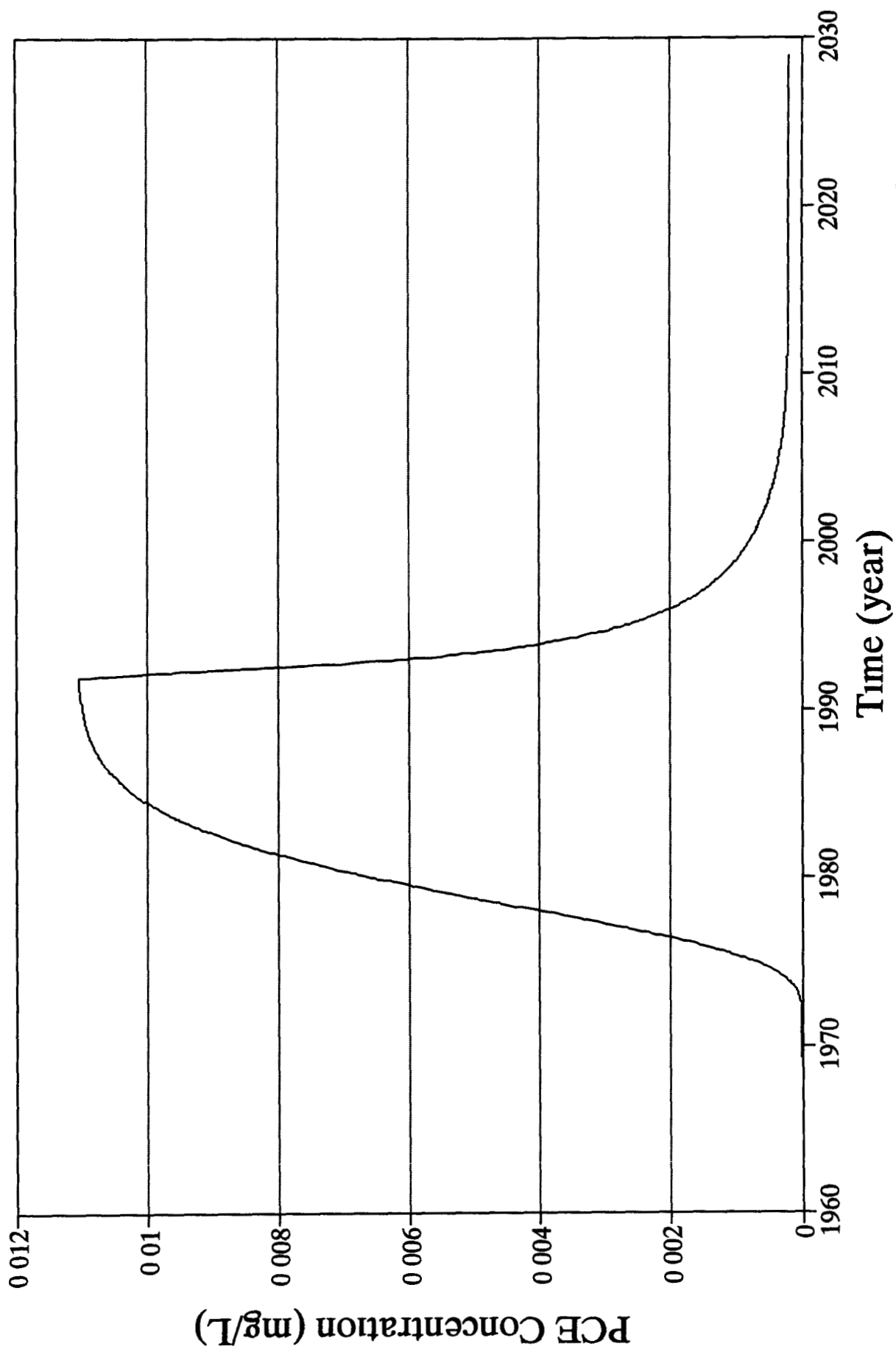


Figure B-57

Institutional Control Alternative Woman Creek

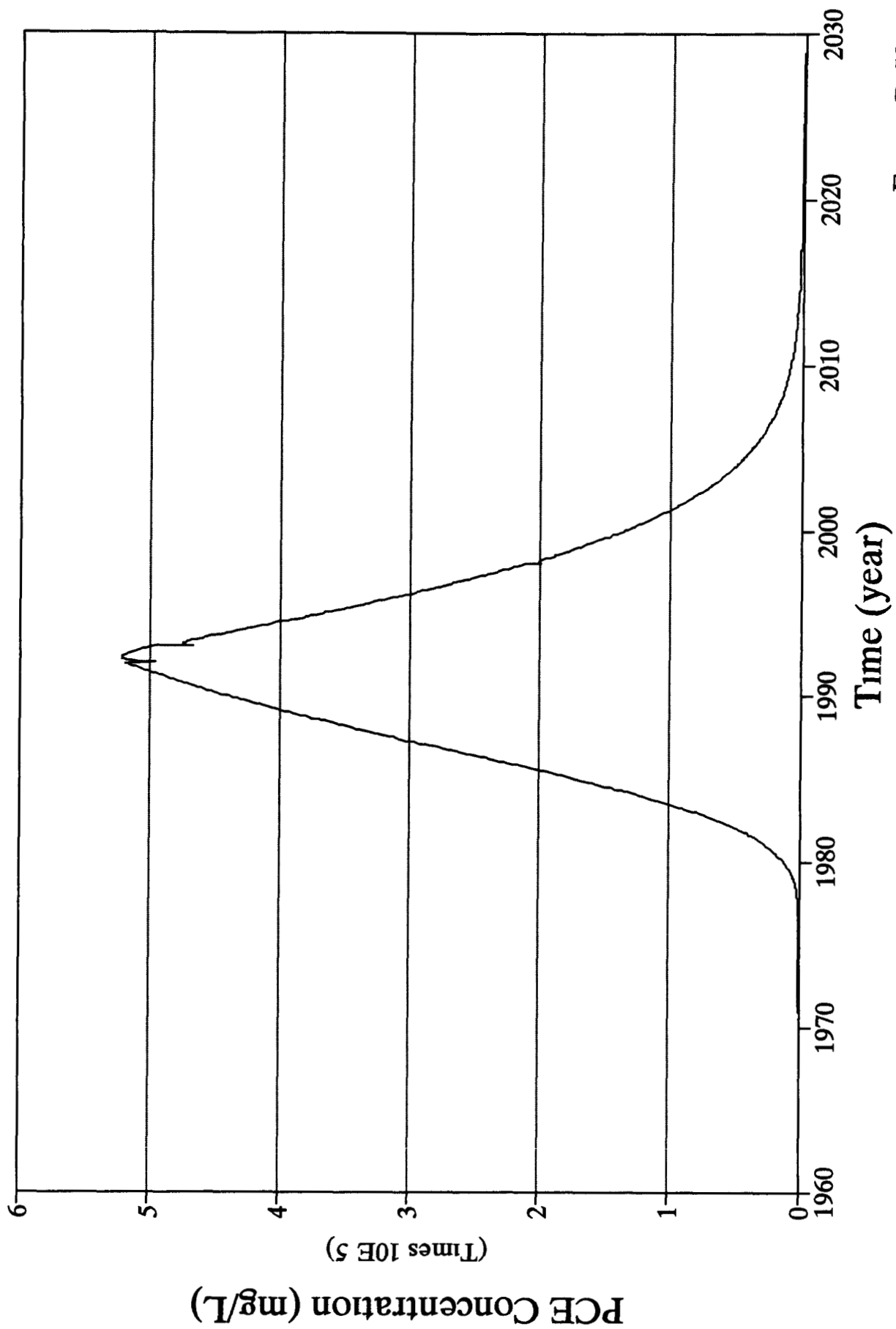


Figure B-58

Institutional Control Alternative Down Gradient of the French Drain

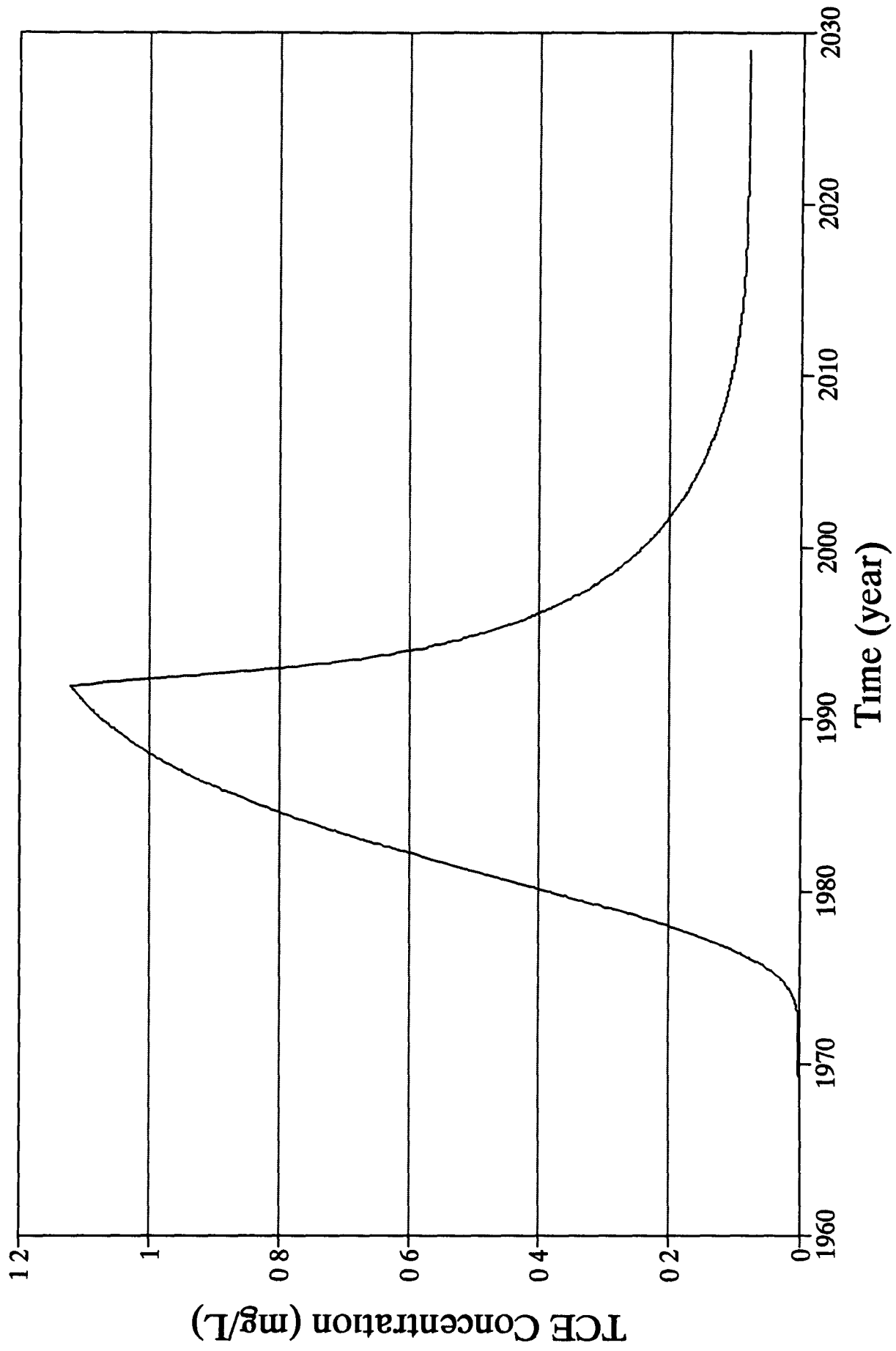


Figure B 59

Institutional Control Alternative Woman Creek

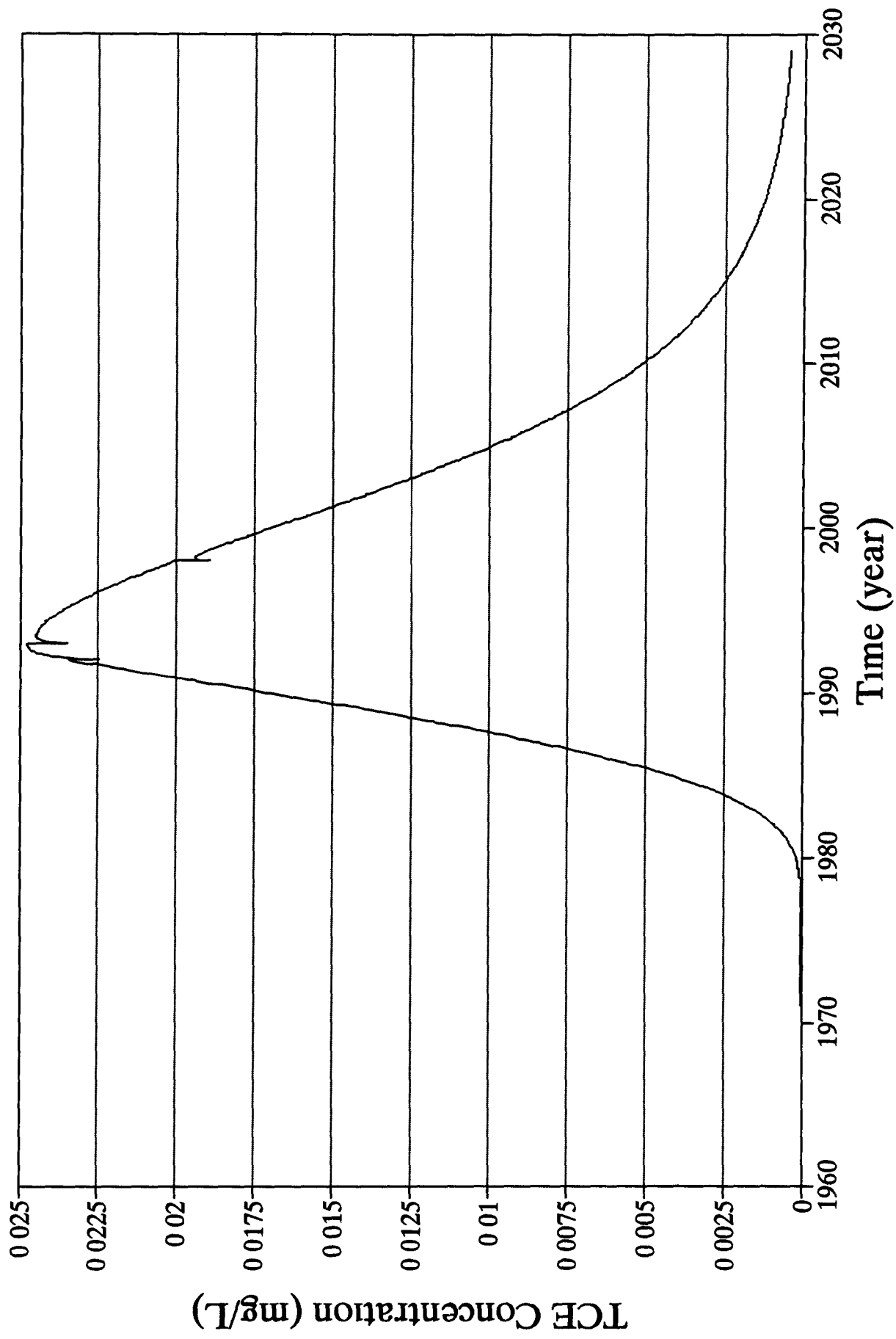


Figure B-60

Institutional Control Alternative Down Gradient of the French Drain

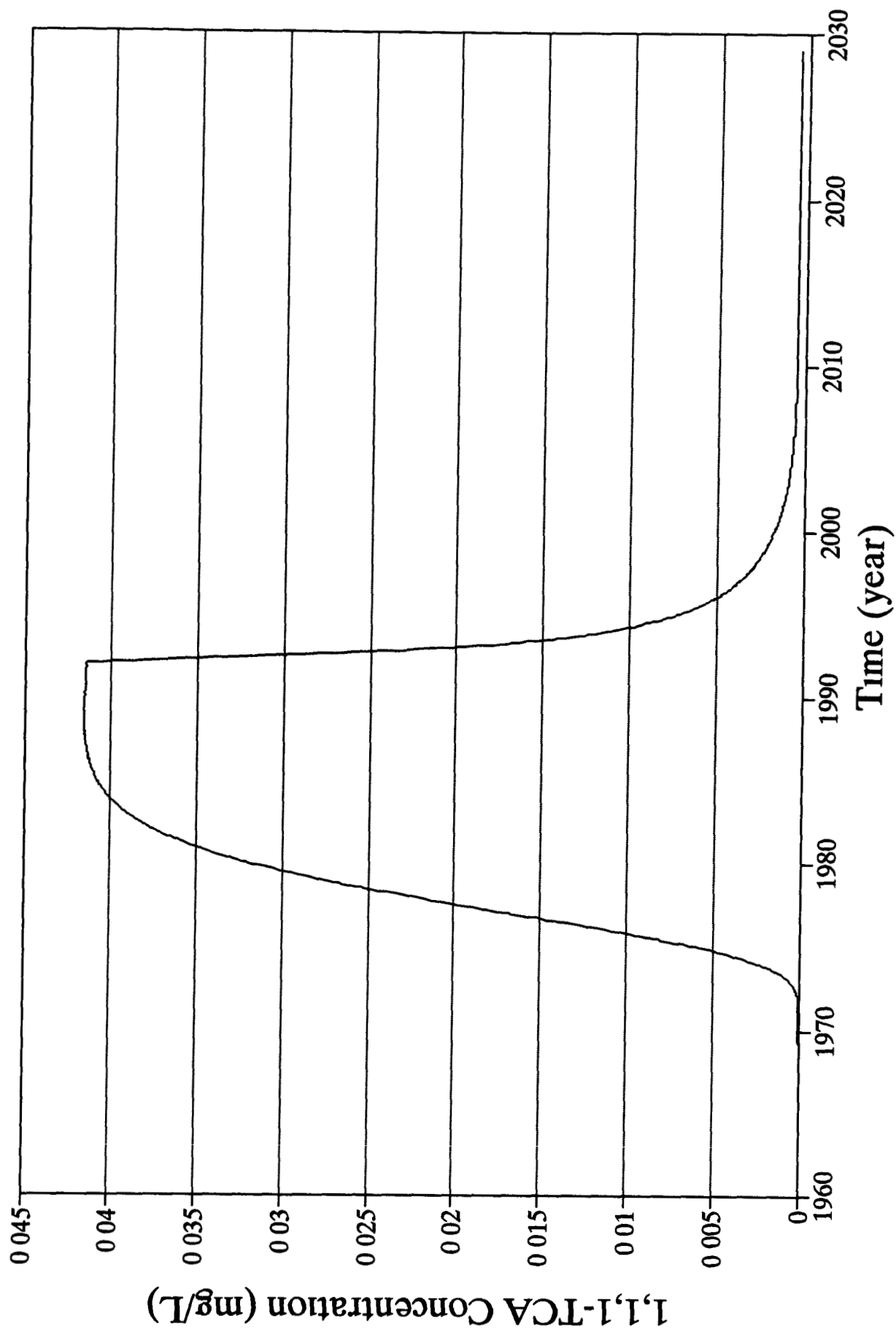


Figure B-61

Institutional Control Alternative Woman Creek

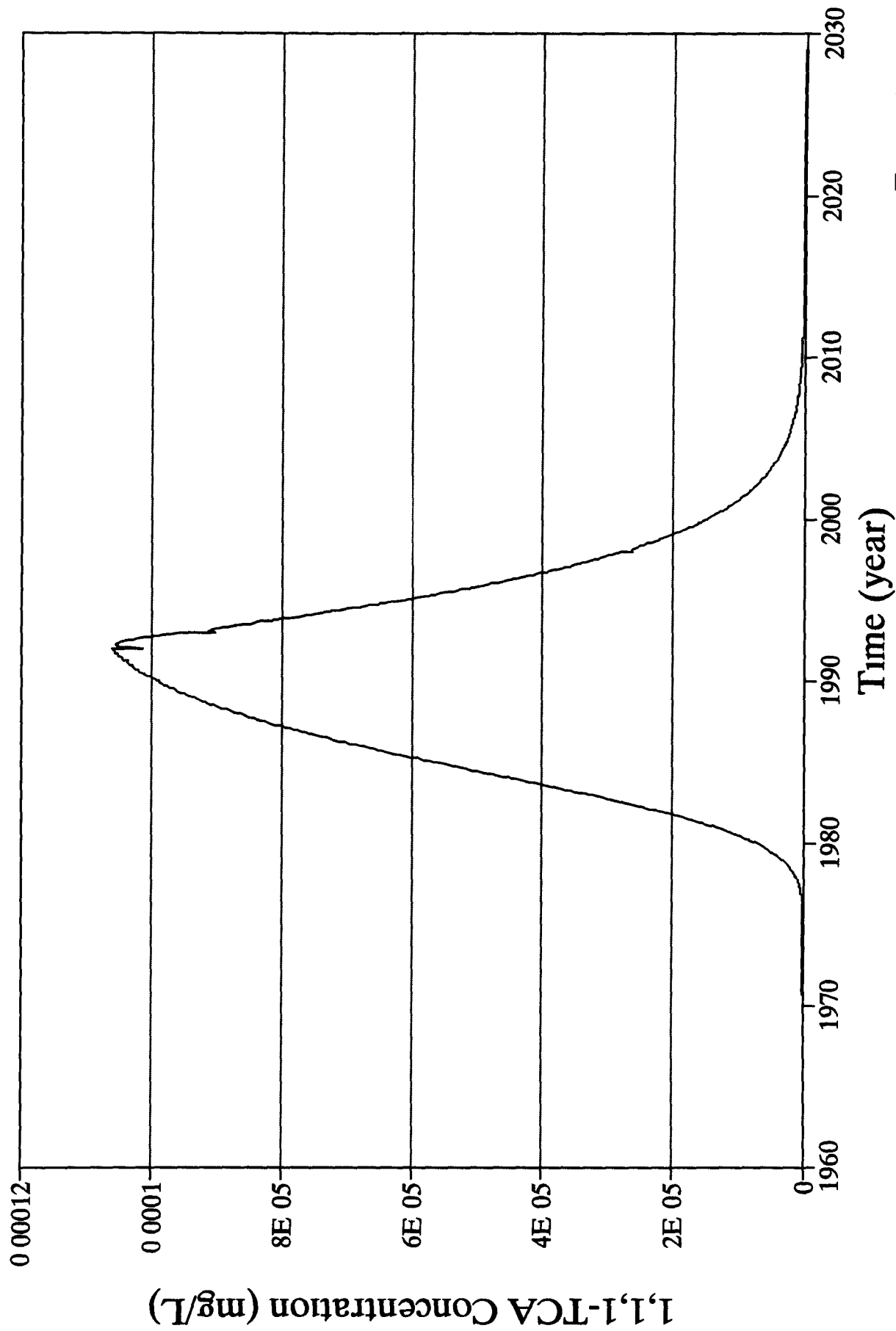


Figure B-62

Institutional Control Alternative Down Gradient of the French Drain

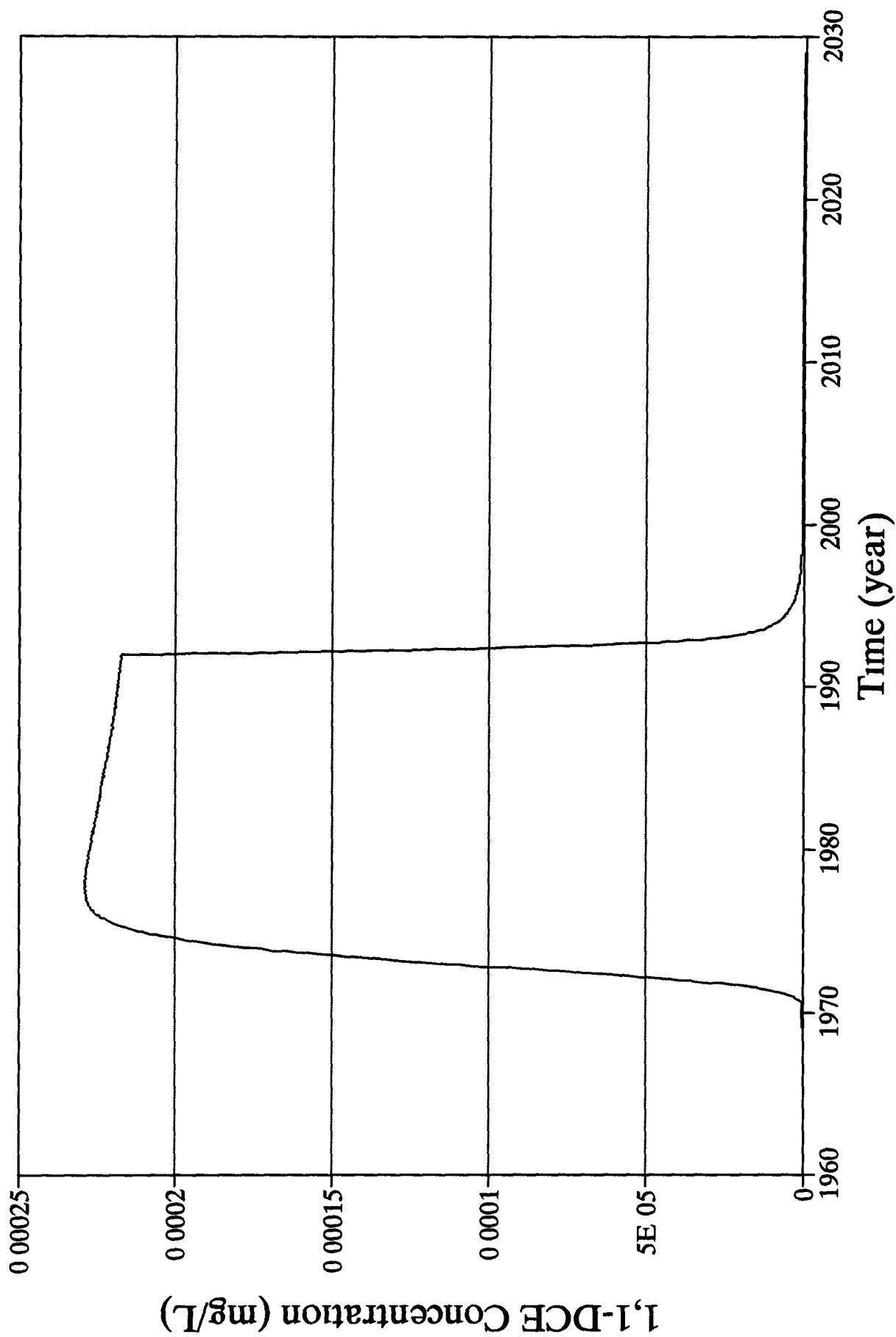


Figure B-63

Institutional Control Alternative Woman Creek

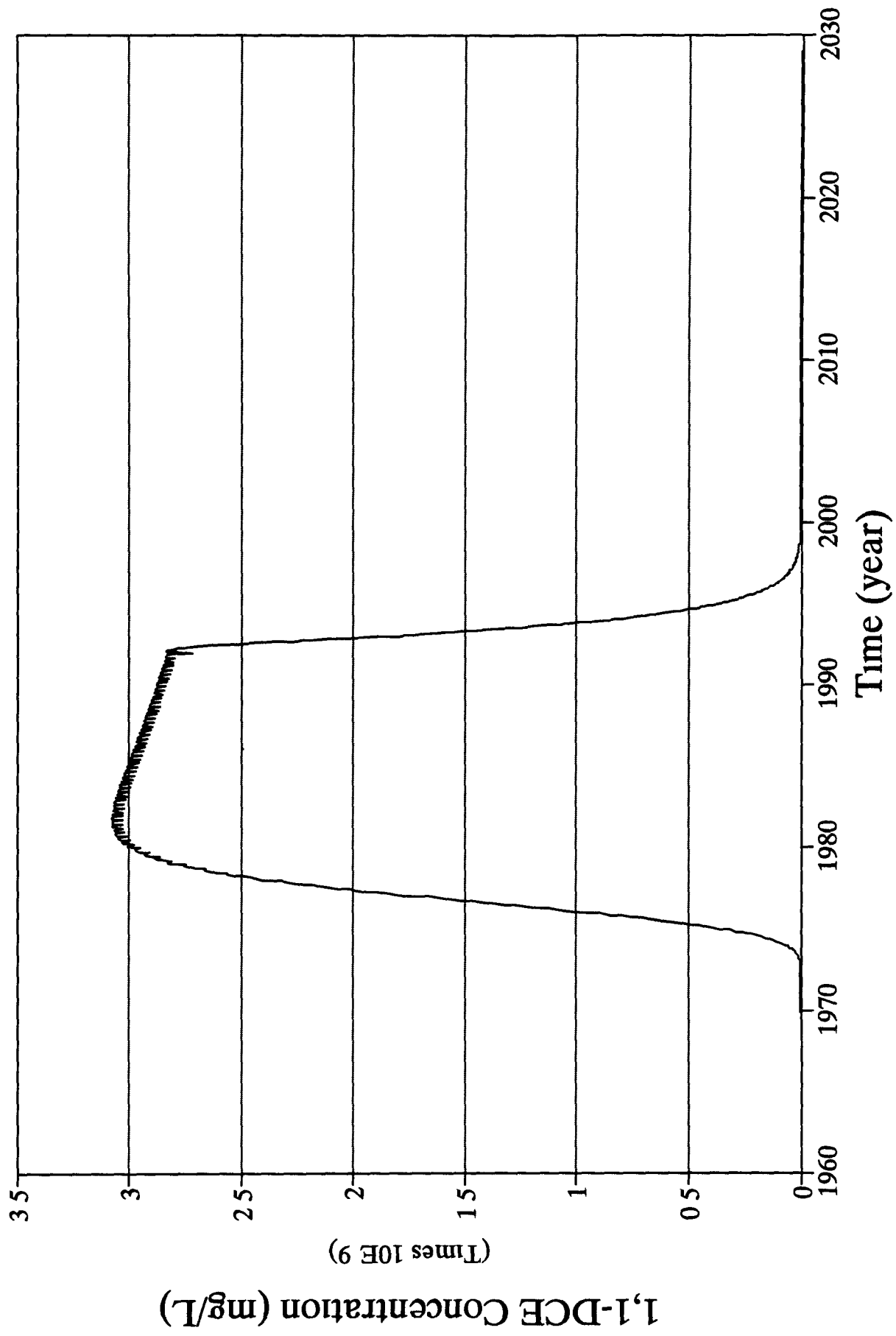


Figure B-64

Institutional Control Alternative Down Gradient of the French Drain

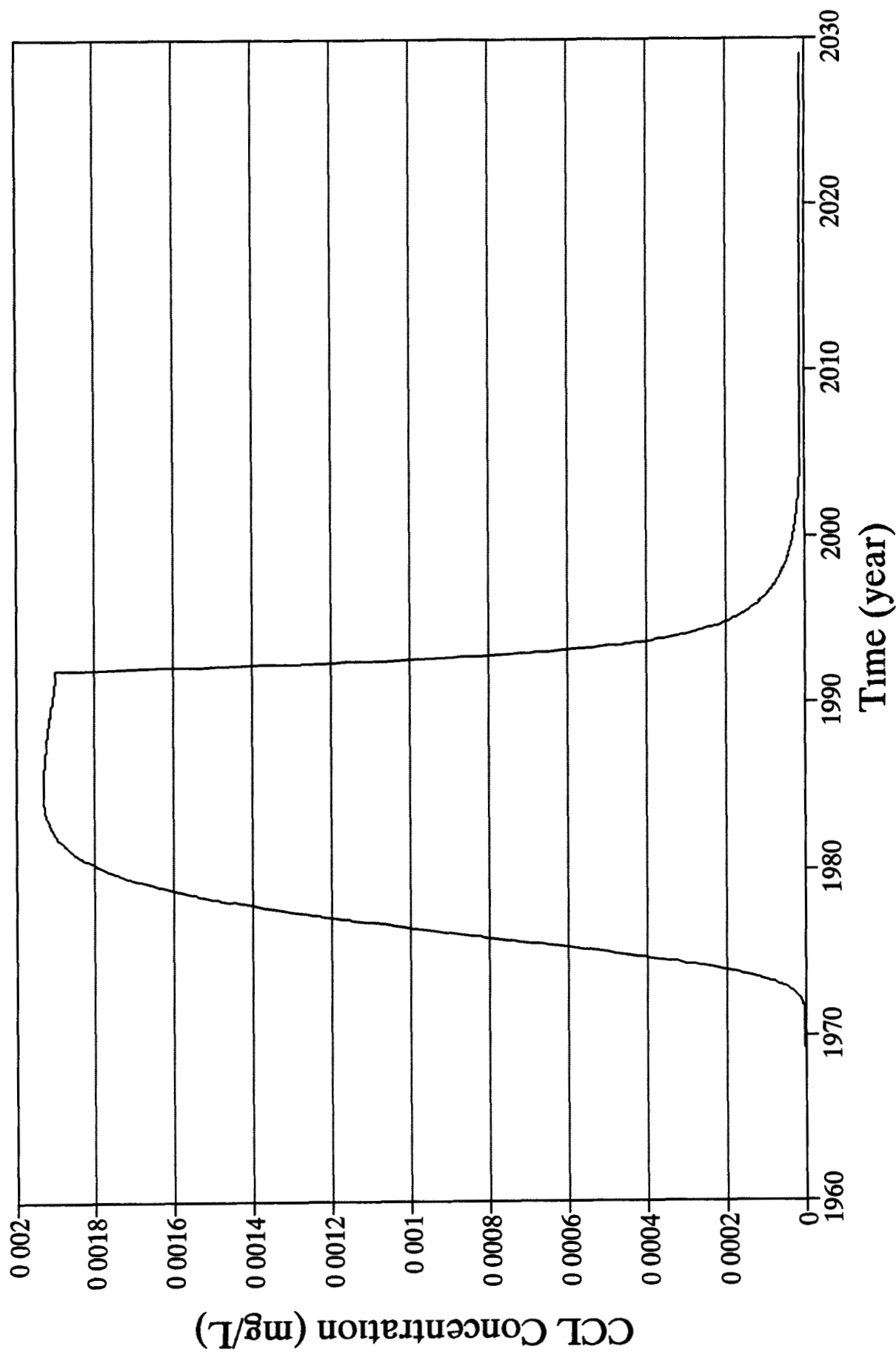


Figure B-65

Institutional Control Alternative Woman Creek

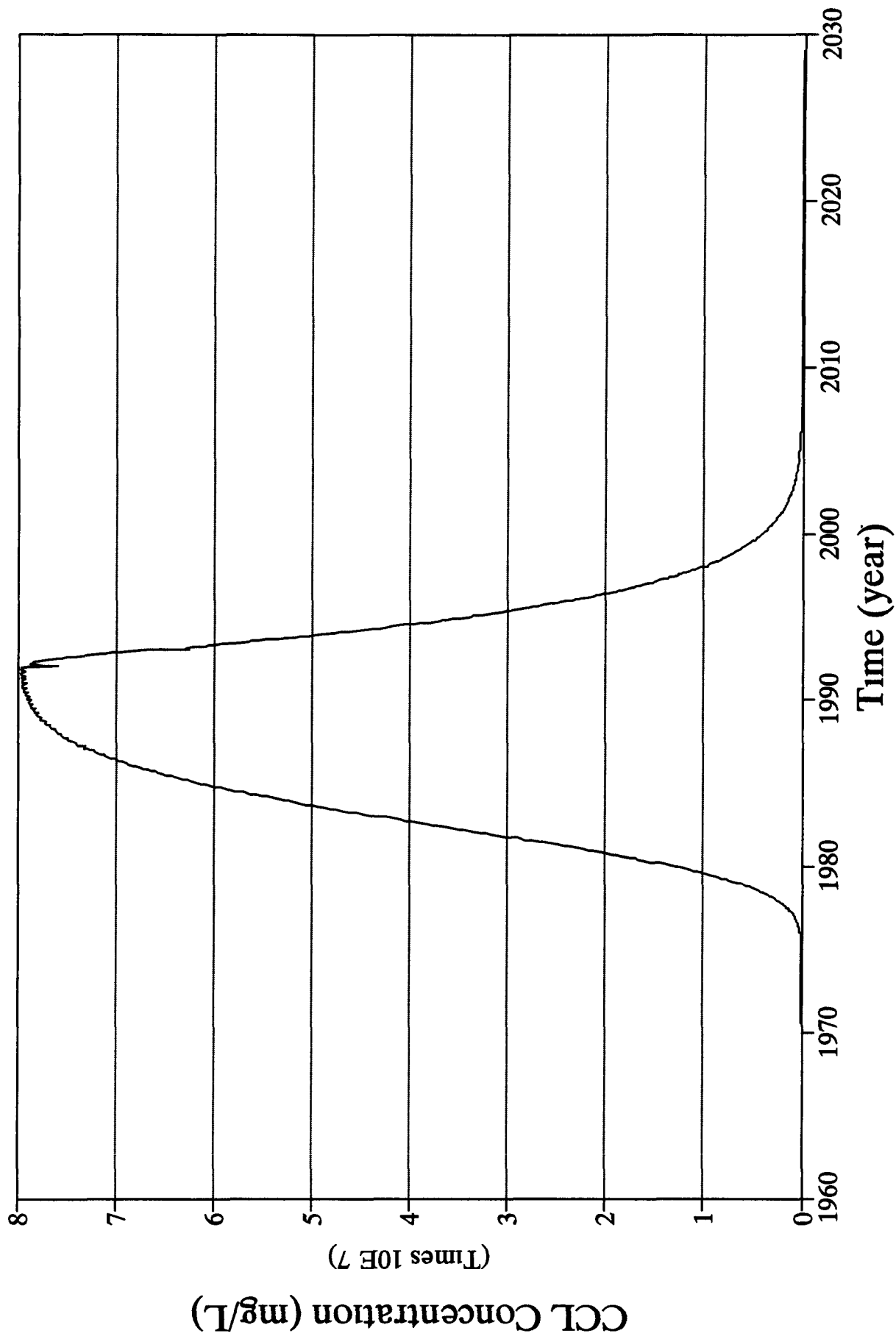


Figure B-66

Remediation Alternative Down Gradient of the French Drain

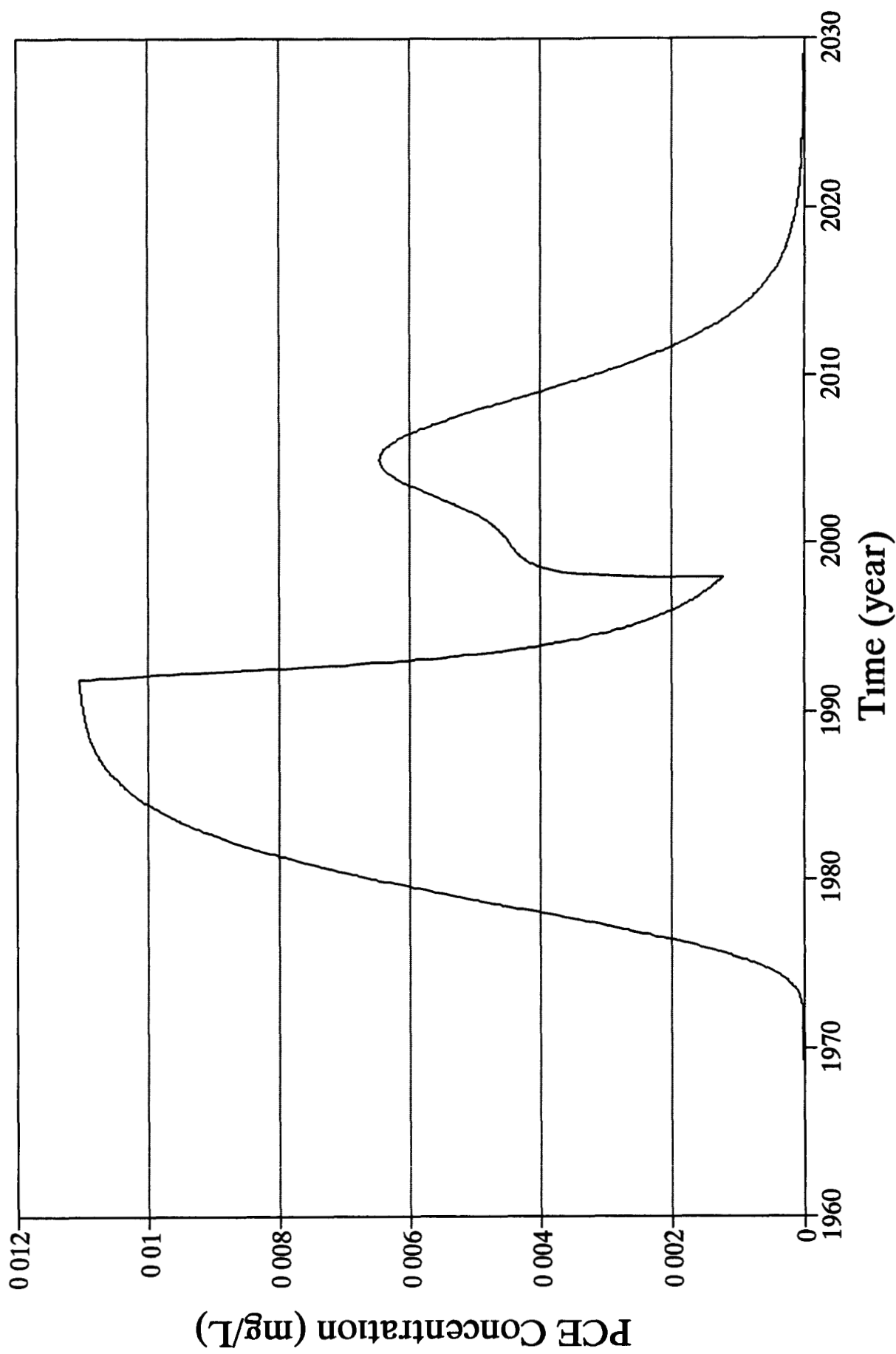


Figure B-67

Remediation Alternative Woman Creek

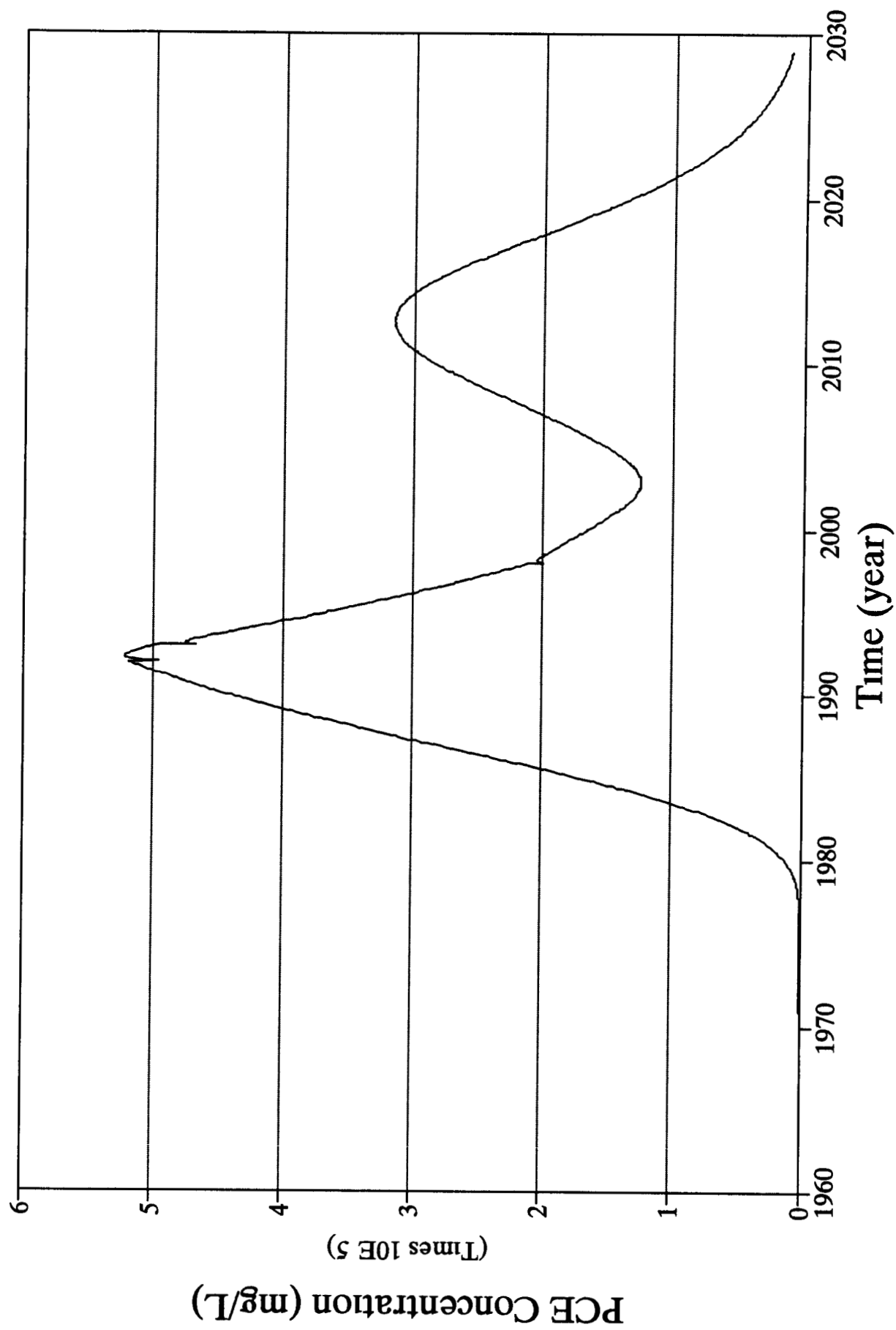


Figure B-68

Remediation Alternative Down Gradient of the French Drain

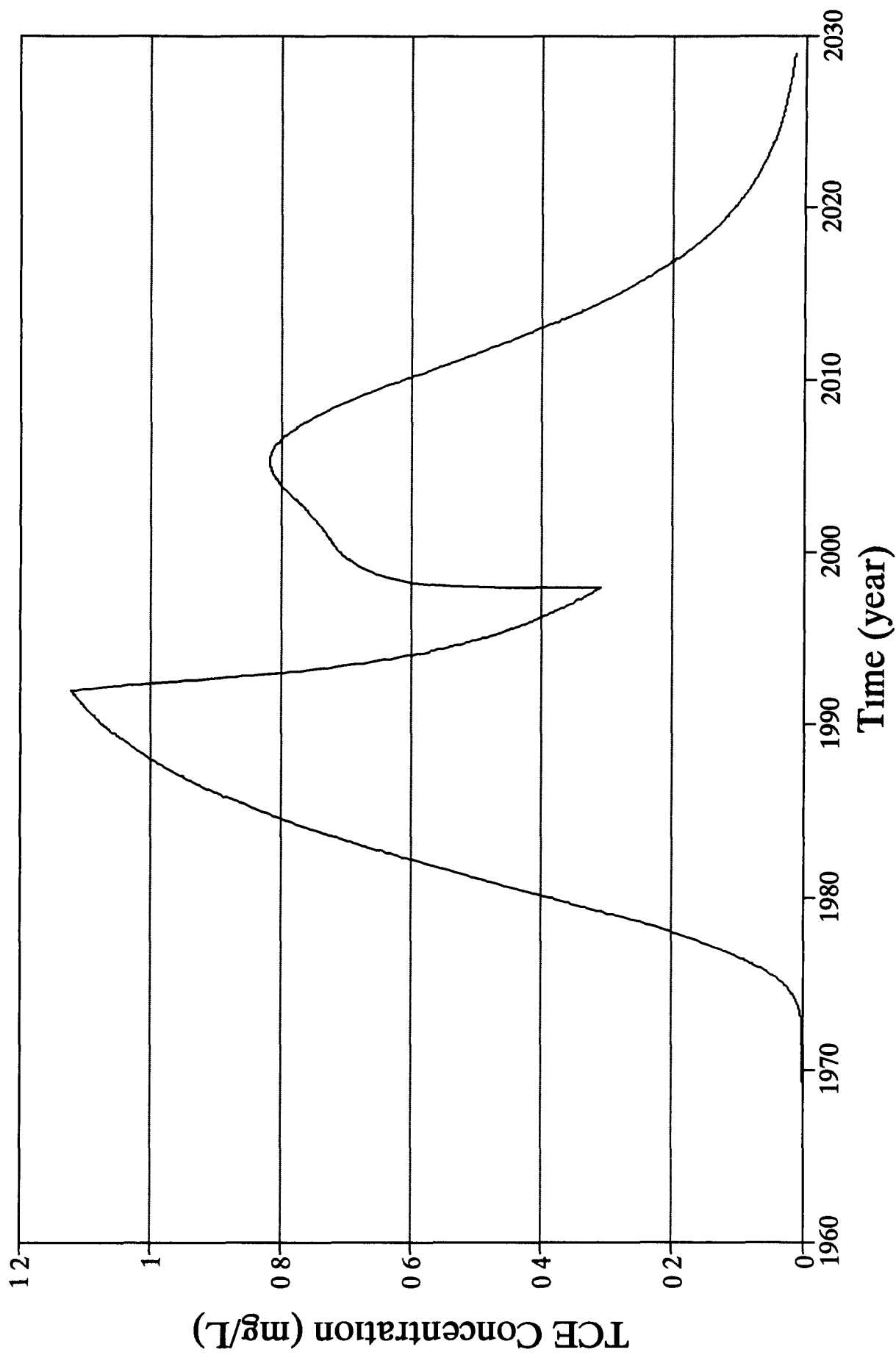


Figure B-69

Remediation Alternative Woman Creek

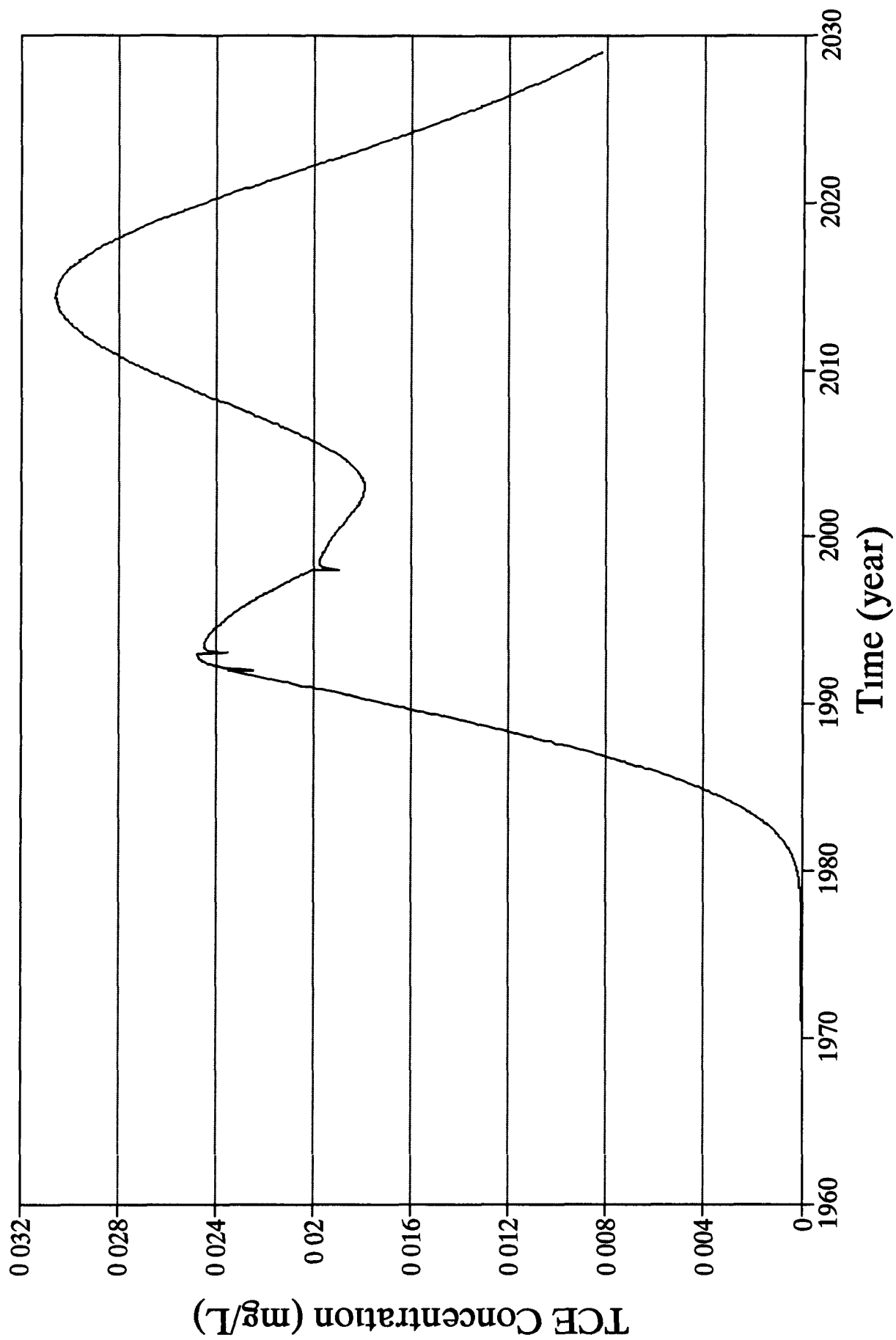


Figure B-70

Remediation Alternative Down Gradient of the French Drain

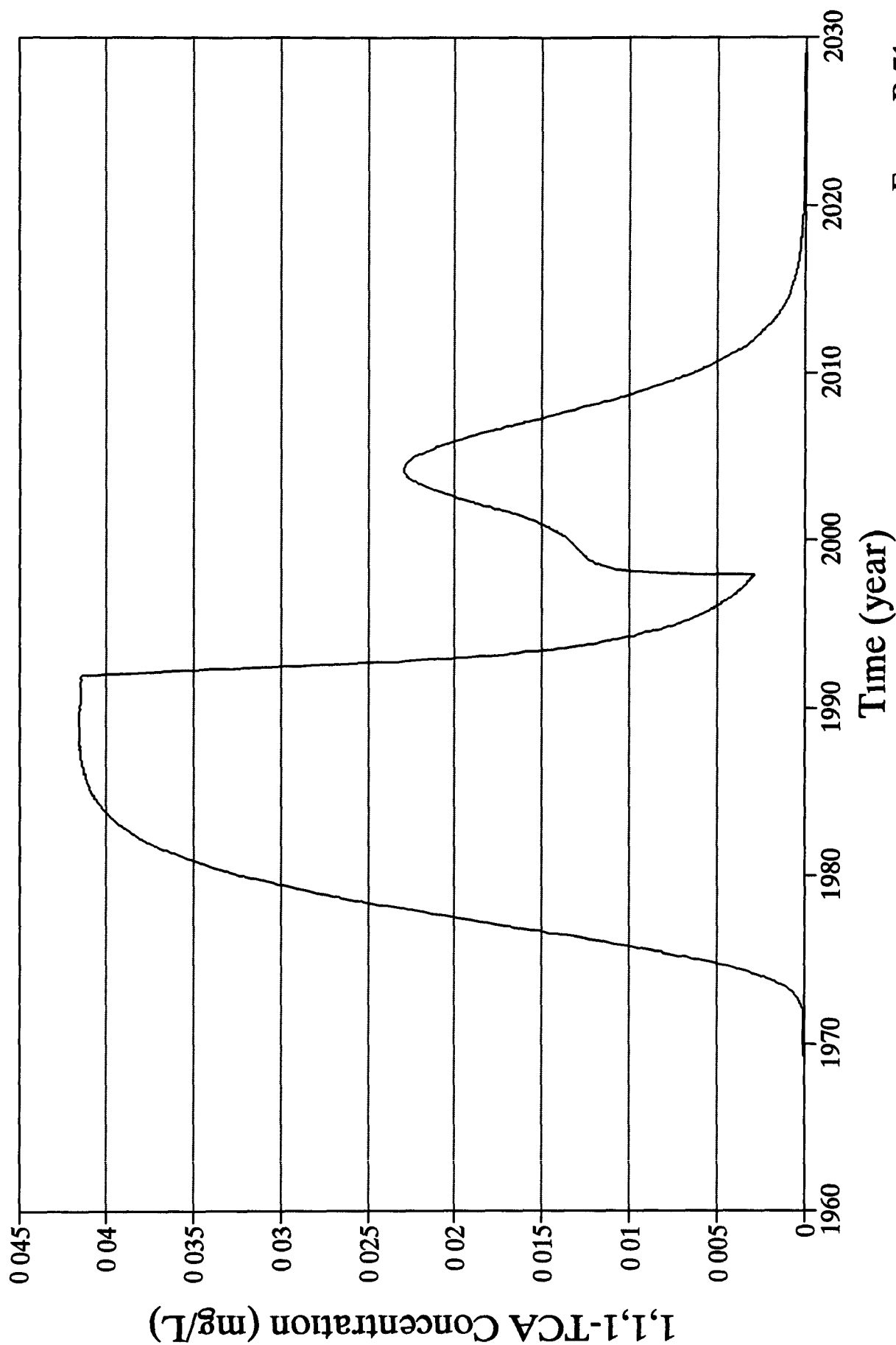


Figure B-71

Remediation Alternative Woman Creek

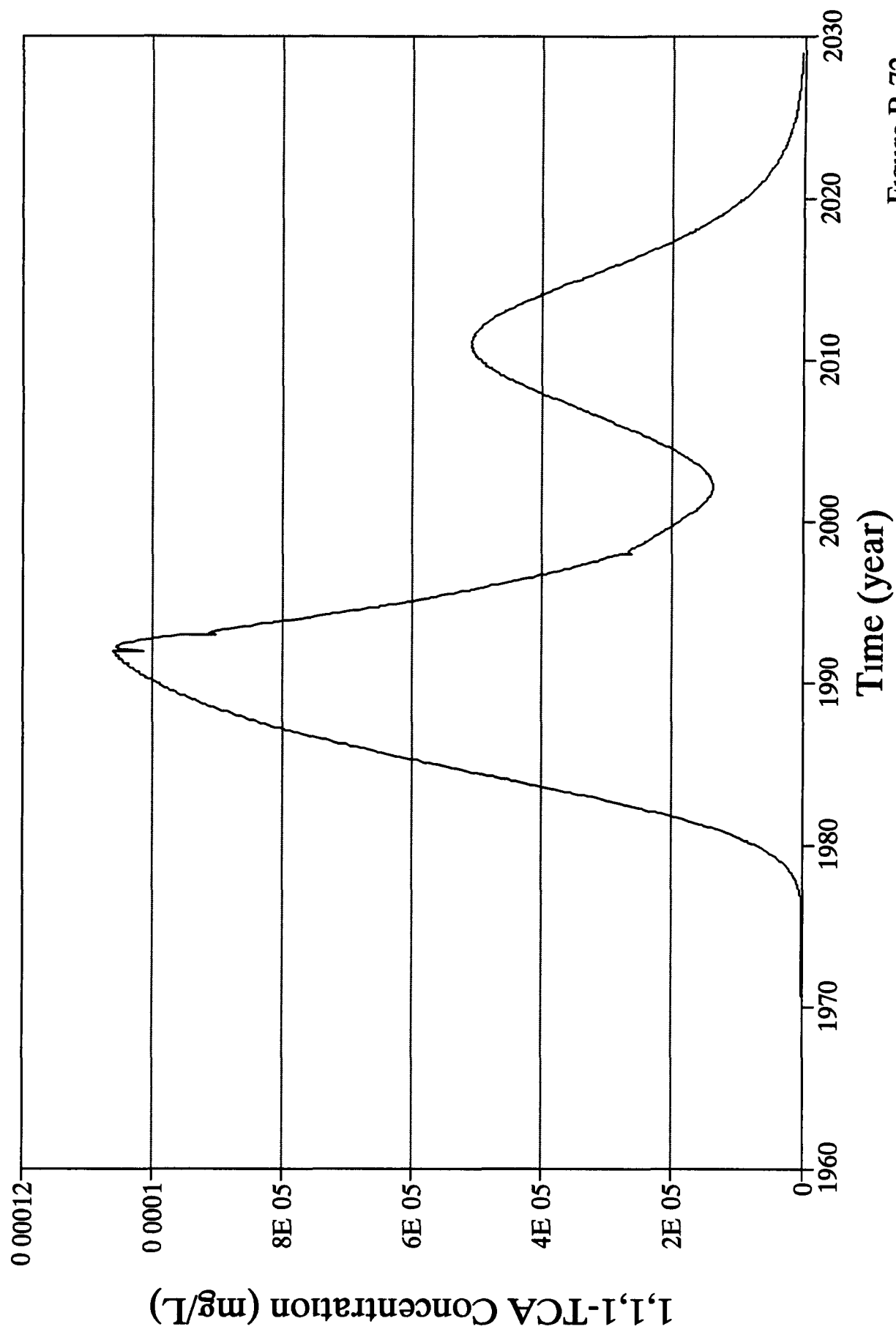


Figure B-72

Remediation Alternative Down Gradient of the French Drain

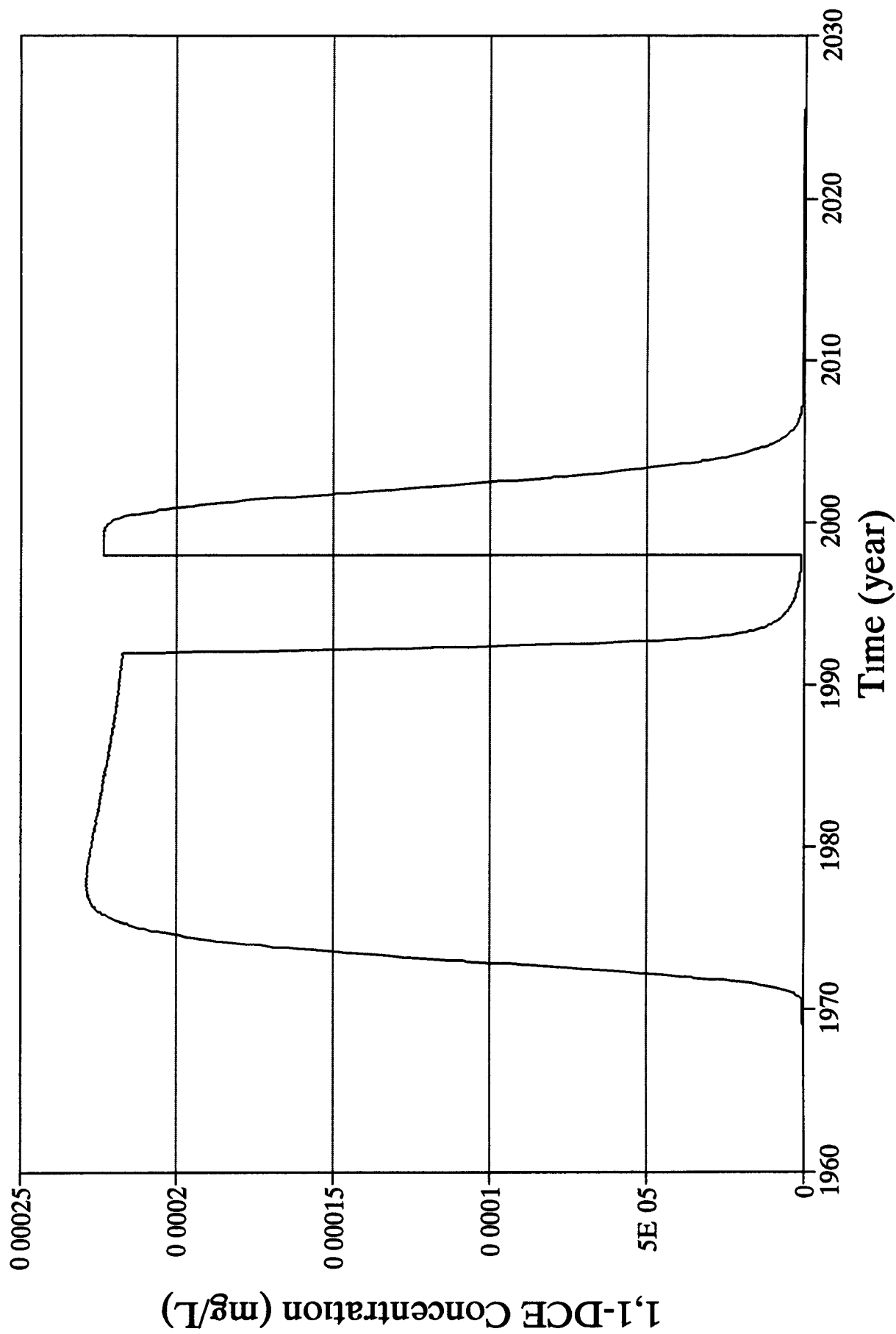


Figure B-73

Remediation Alternative Woman Creek

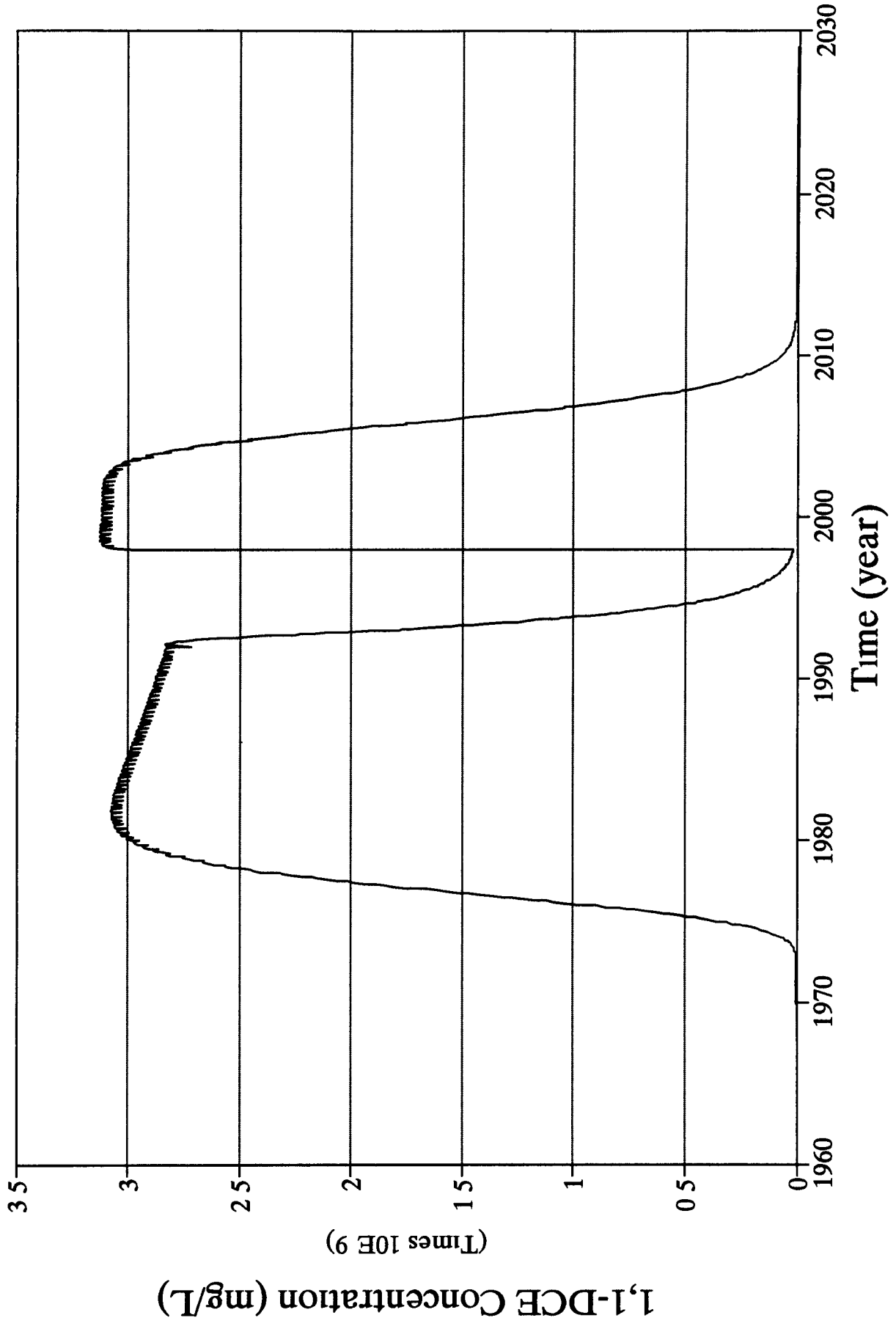


Figure B-74

Remediation Alternative Down Gradient of the French Drain

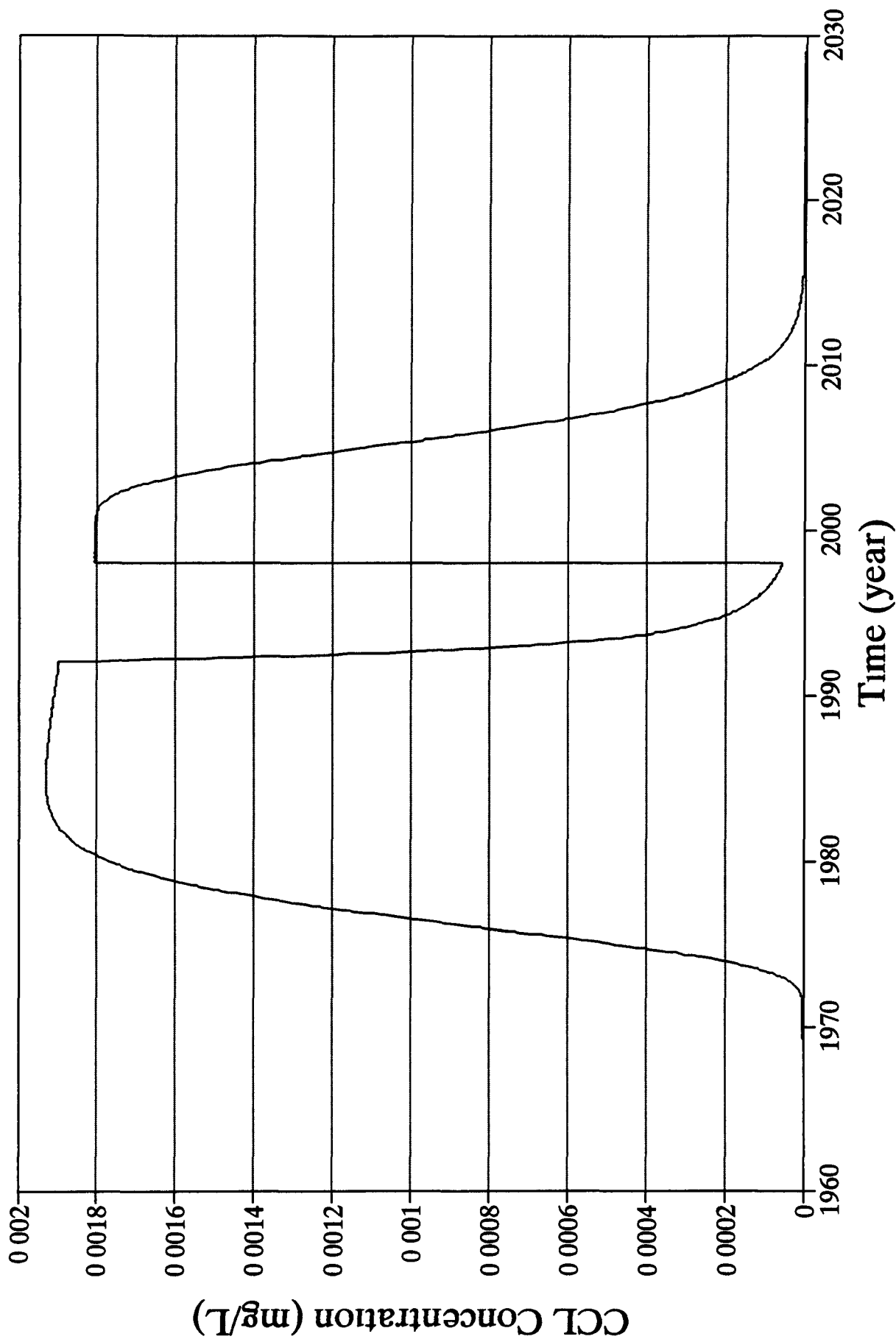


Figure B-75

Remediation Alternative Woman Creek

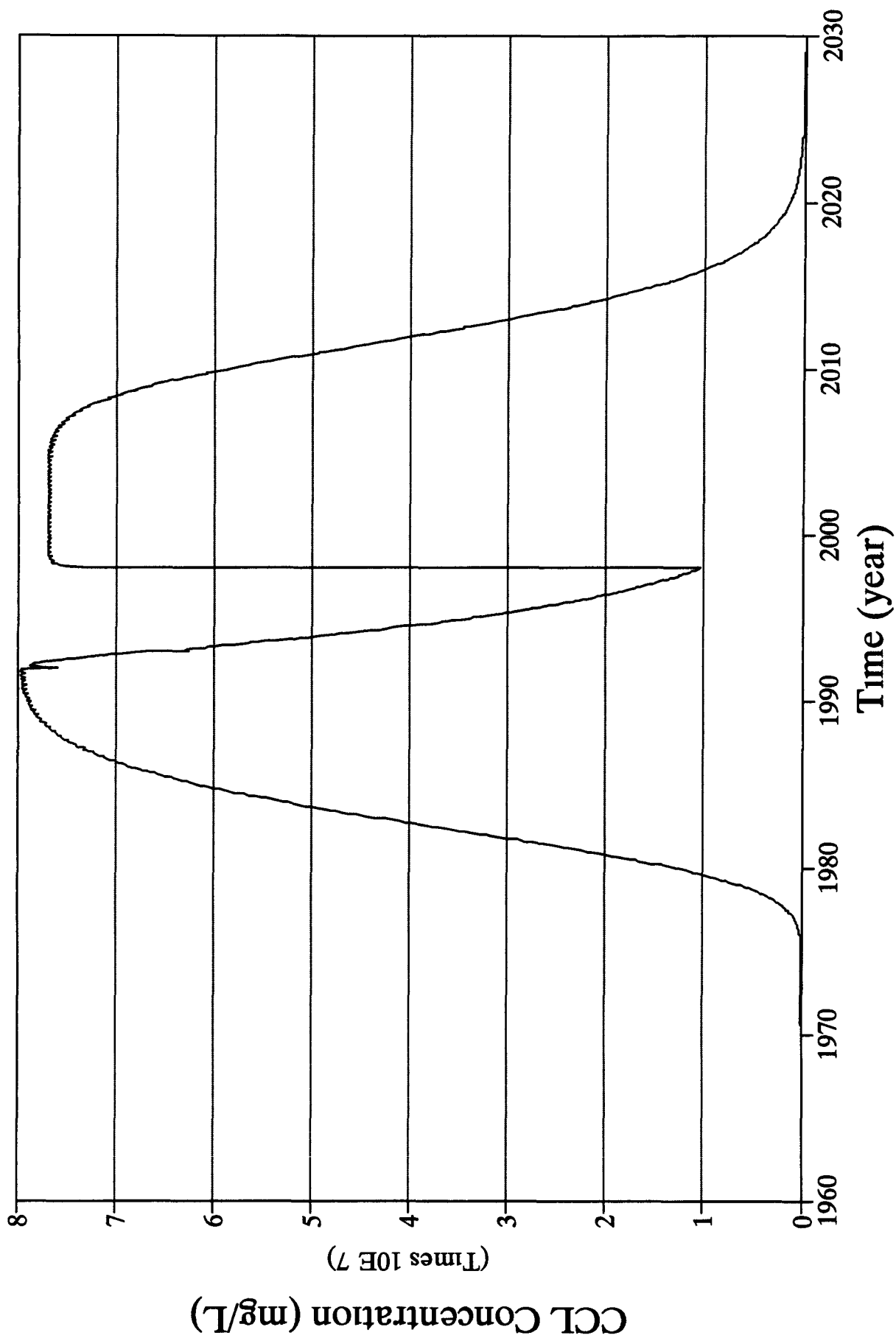


Figure B-76

Relative Difference Between Scenarios Down Gradient of the French Drain

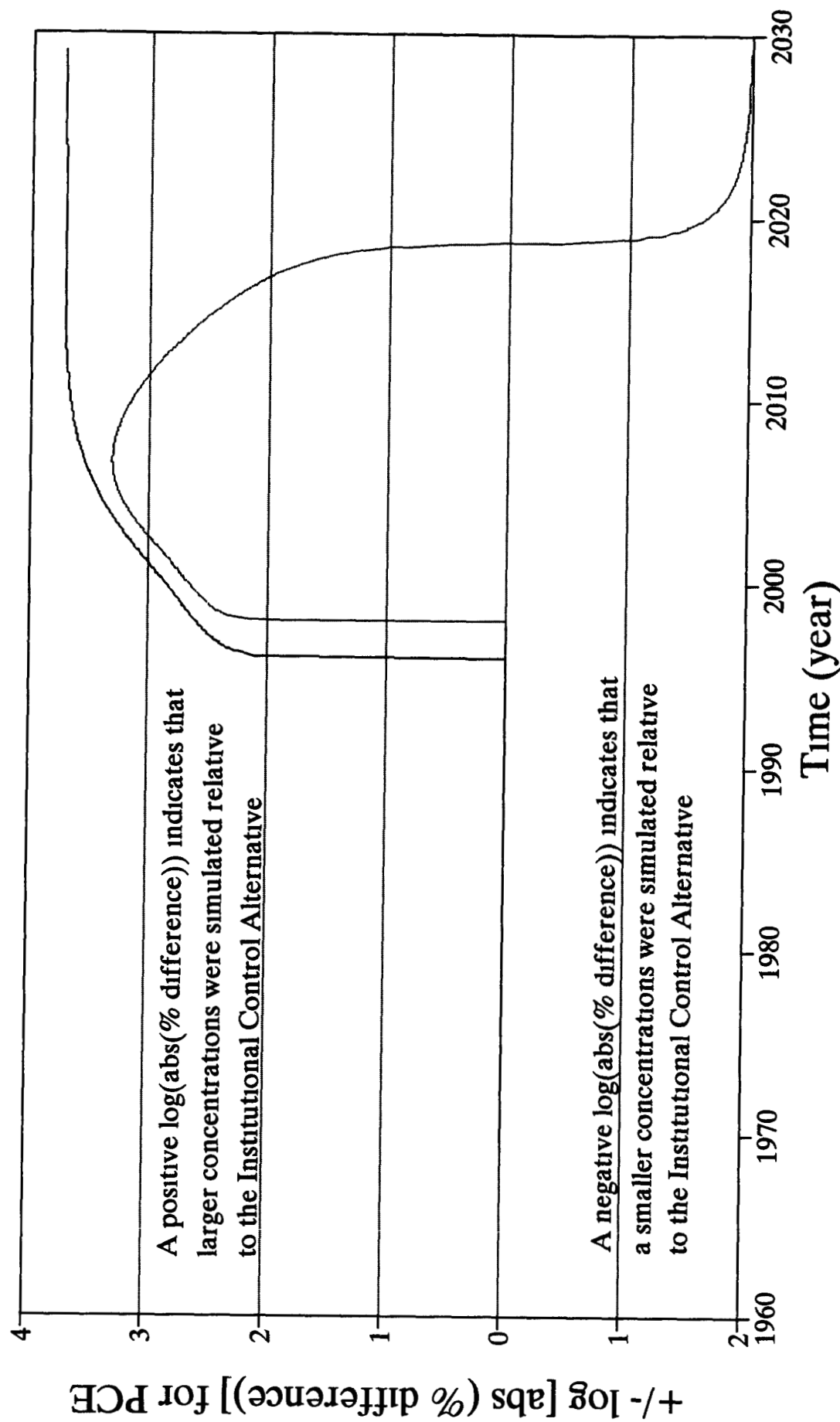


Figure B-77

Relative Difference Between Scenarios Woman Creek

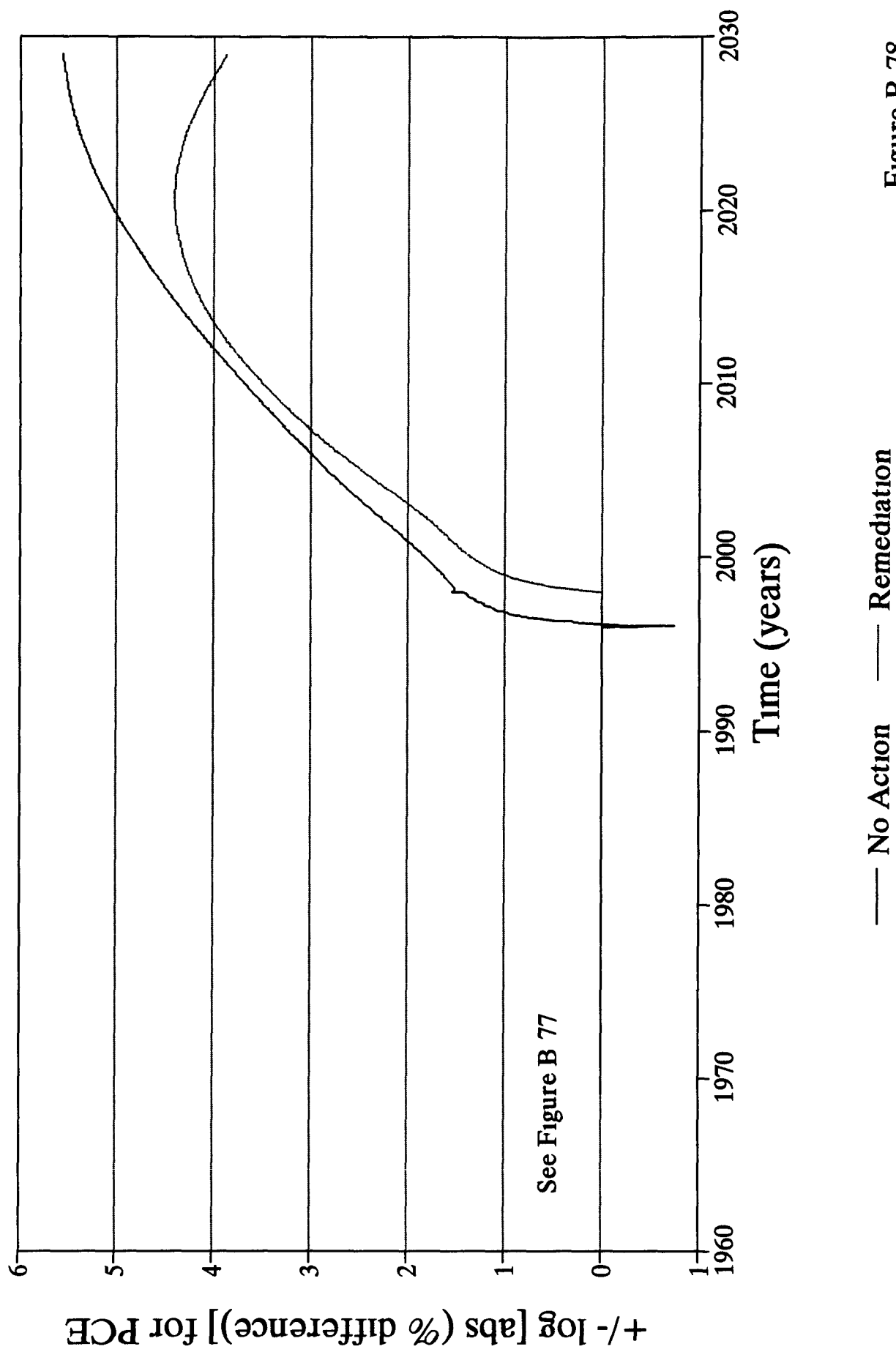


Figure B-78

Relative Difference Between Scenarios Down Gradient of the French Drain

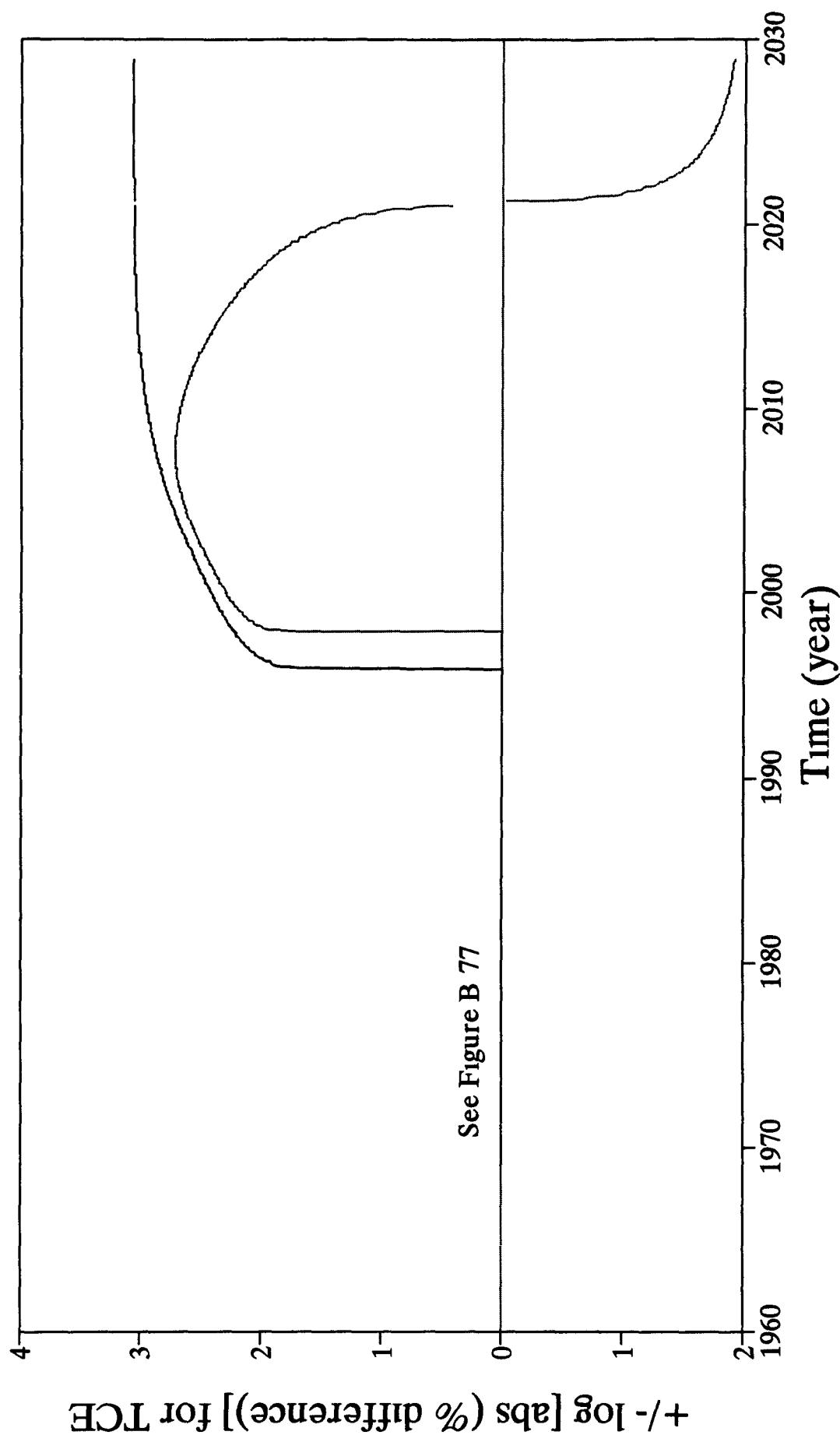
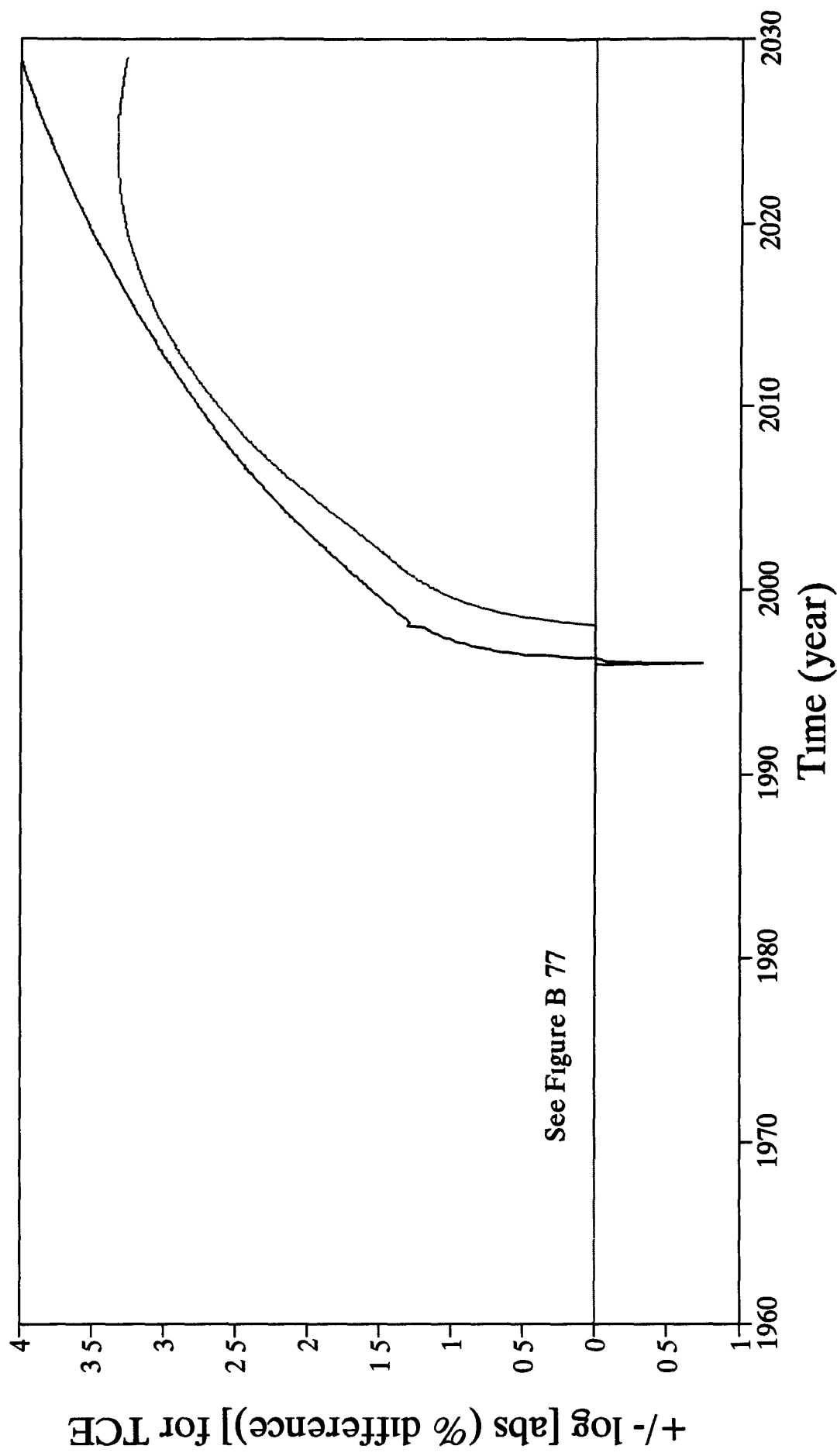


Figure B-79

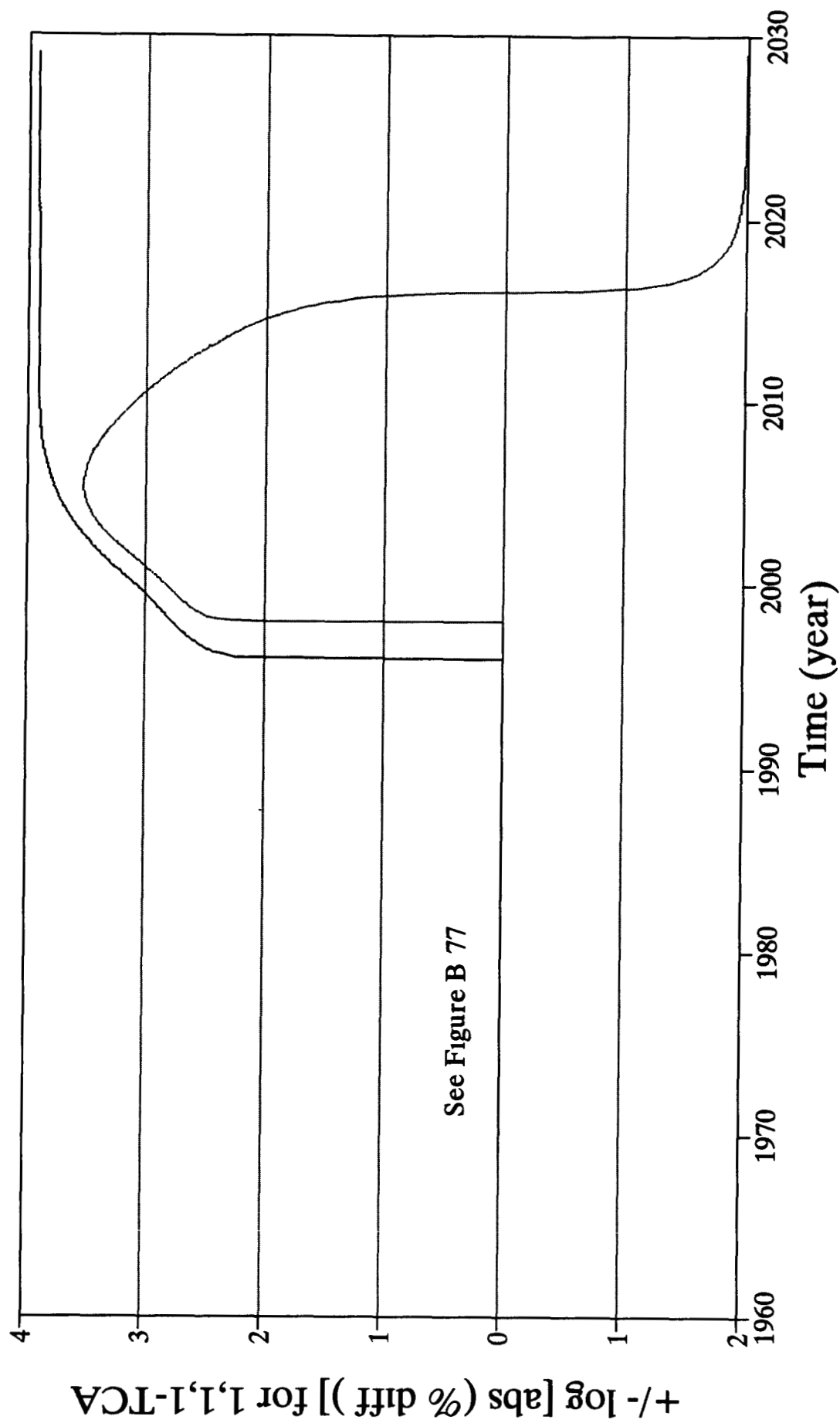
Relative Difference Between Scenarios Woman Creek



— No Action — Remediation

Figure B 80

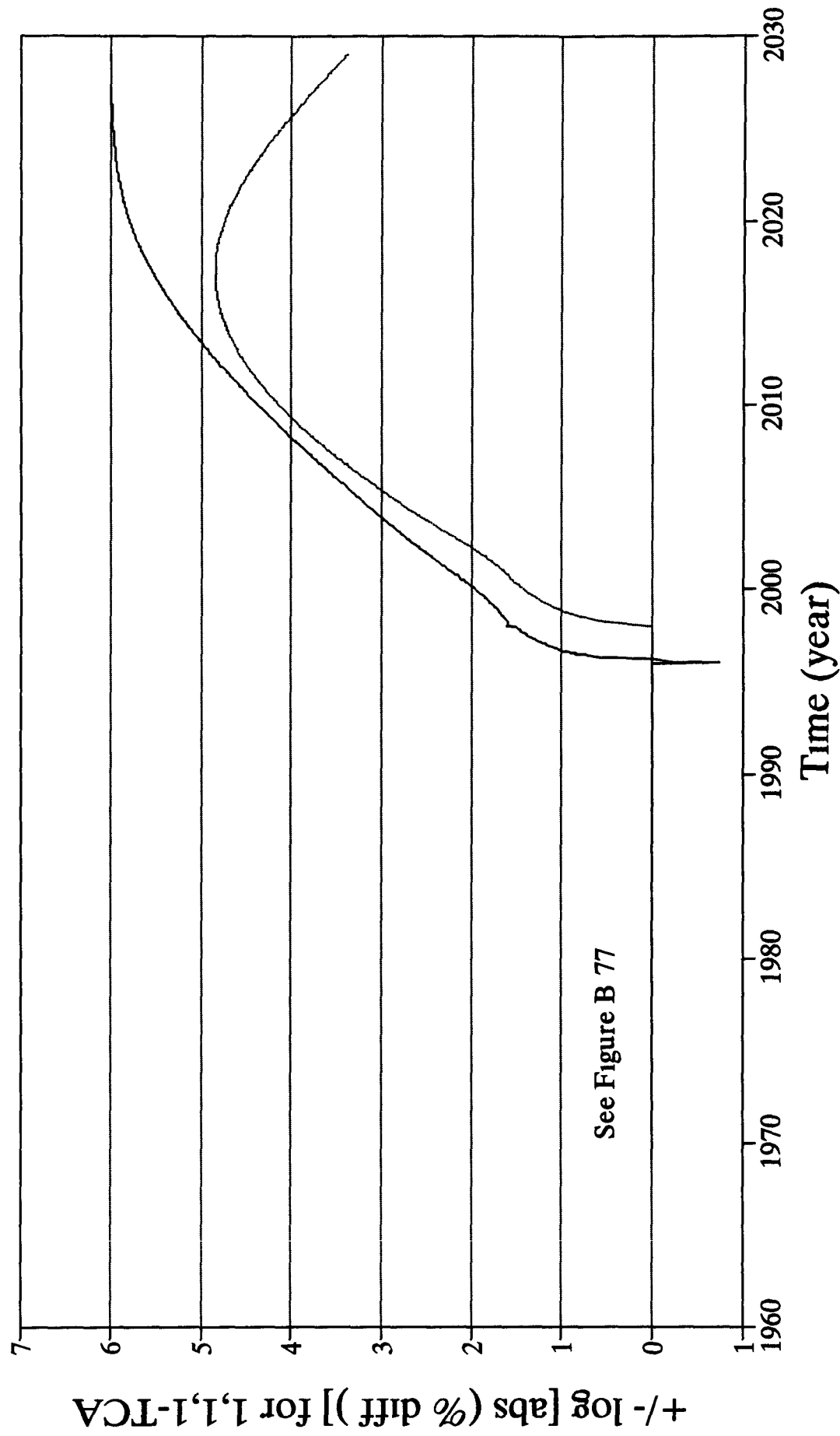
Relative Difference Between Scenarios Down Gradient of the French Drain



— No Action — Remediation

Figure B-81

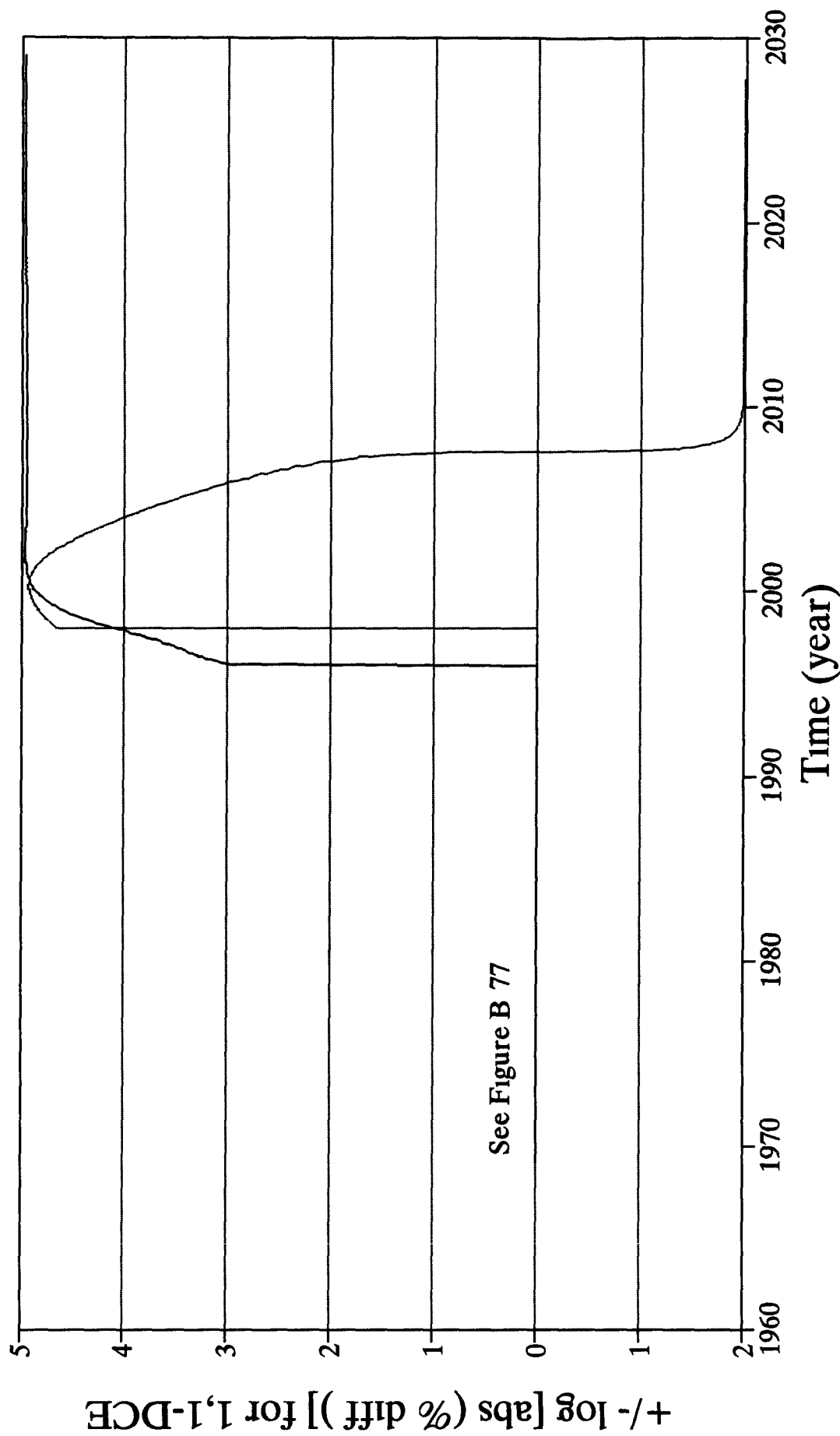
Relative Difference Between Scenarios Woman Creek



— No Action — Remediation

Figure B-82

Relative Difference Between Scenarios Down Gradient of the French Drain



— No Action — Remediation

Figure B 83

Relative Difference Between Scenarios Woman Creek

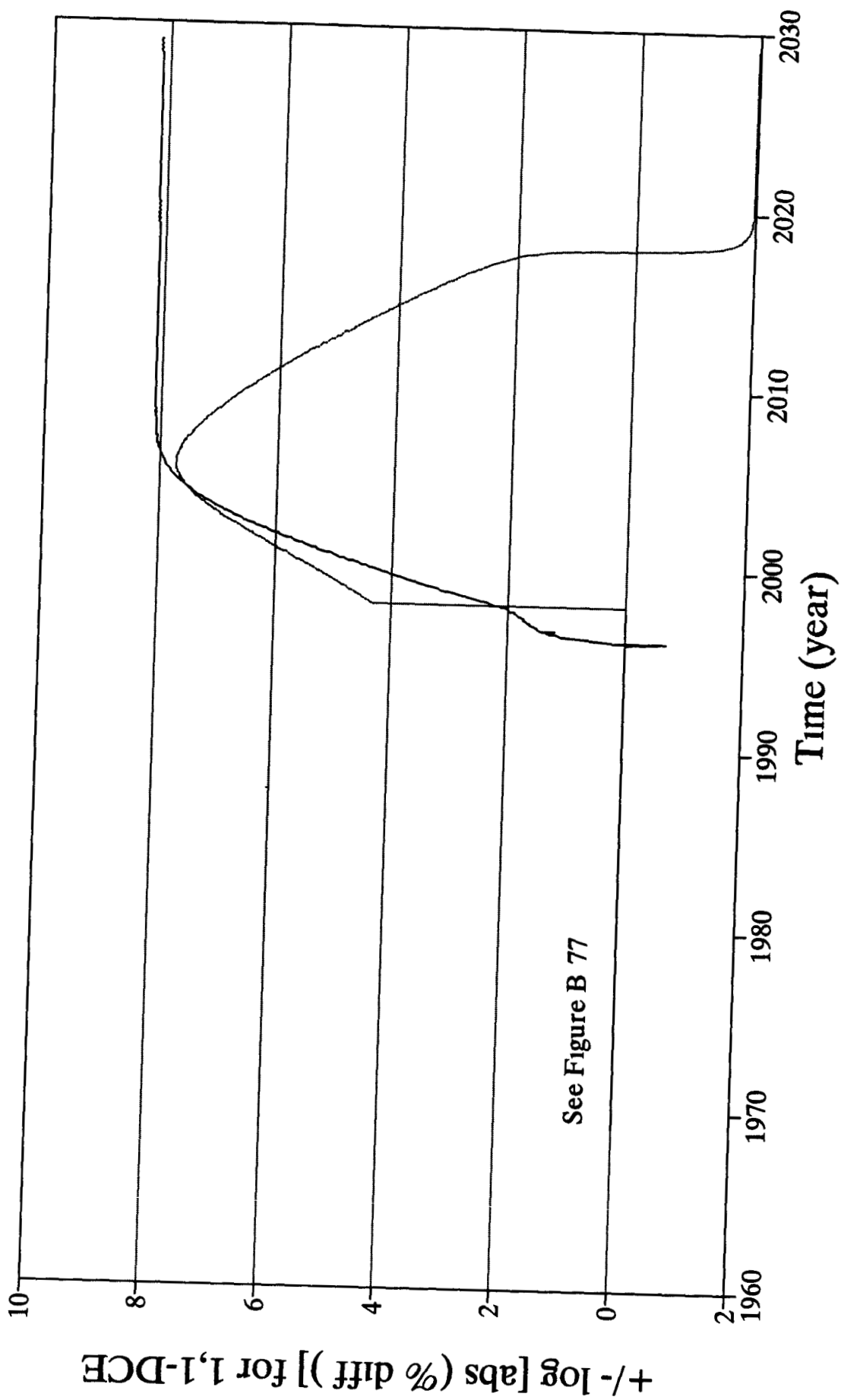
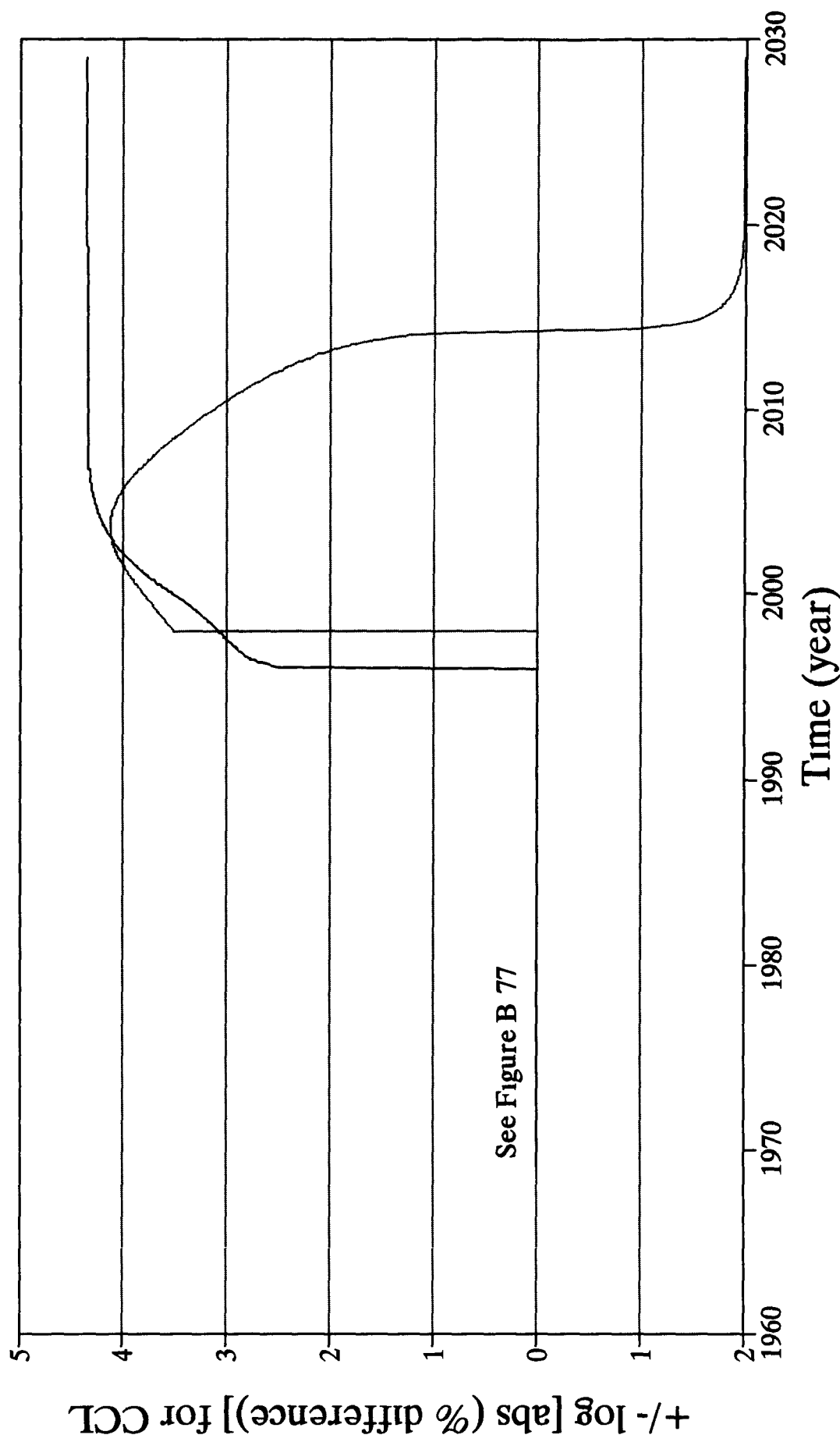


Figure B-84

Relative Difference Between Scenarios Down Gradient of the French Drain



— No Action - - - Remediation

Figure B-85

Relative Difference Between Scenarios Woman Creek

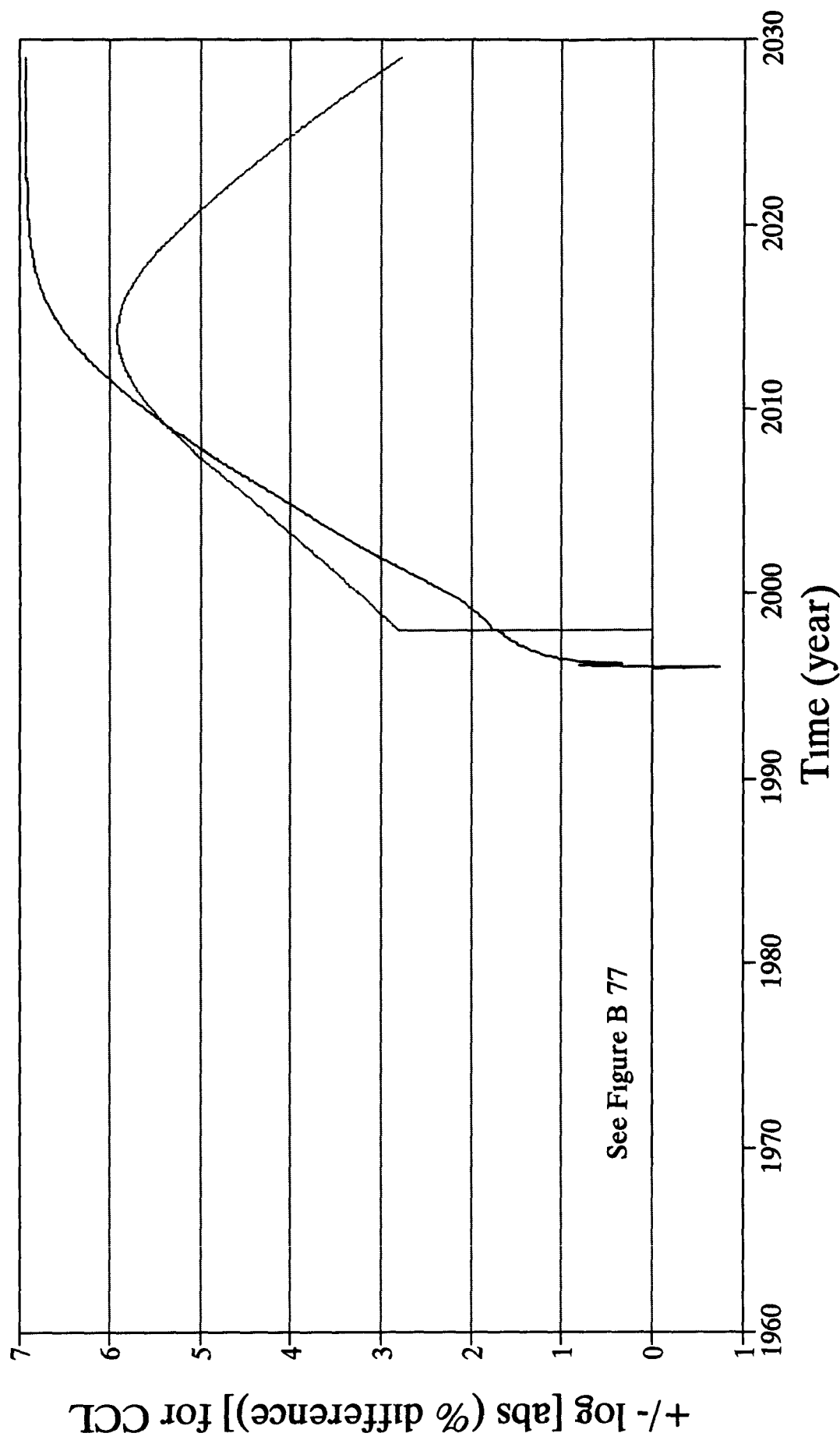


Figure B-86

APPENDIX C TABLE OF CONTENTS

C 1 0	INTRODUCTION	1
C 2 0	EXPOSURE PATHWAYS AND RECEPTORS OF CONCERN	2
C 2 1	Exposure Pathways	2
C 2 2	Receptors of Concern	3
C 2 2 1	Future Onsite Resident	3
C 2 2 2	Future Onsite Office Worker	4
C 3 0	CONTAMINANTS OF CONCERN	5
C 3 1	Contaminants Identified	5
C 3 2	Concentrations of Contaminants Identified	6
C 4 0	EXPOSURE ASSESSMENT AND INTAKE EQUATIONS	8
C 4 1	Ingestion of Water	8
C 4 2	Dermal Contact With Water	9
C 4 3	Inhalation of Airborne Contaminants	10
C 4 4	Contaminant Intakes	11
C 5 0	TOXICITY ASSESSMENT	18
C 5 1 1 1	DCE	18
C 5 2 1 1 1	TCA	20
C 5 3	CCl ₄	21
C 5 4	PCE	23
C 6 0	RISK CHARACTERIZATION	25
C 6 1	Risk and Hazard Quotient Calculation	25
C 6 2	Carcinogenic Effects	26
C 6 3	Noncarcinogenic Effects	27
C 7 0	UNCERTAINTY ANALYSIS	35
C 7 1	Sources of Uncertainty	35
C 7 1 1	Data Collection and Evaluation	36
C 7 1 2	Exposure Assessment	36
C 7 1 3	Toxicity Assessment	36
C 7 1 4	Risk Characterization	36
C 7 2	Uncertainty in Human Intake Parameters	37
C 7 3	Qualitative Uncertainty Analysis	38
C 8 0	SUMMARY	41
C 9 0	REFERENCES	42

LIST OF TABLES

C 3 1	Contaminant Concentrations	7
C 4 1	Carcinogenic Intakes No Action Scenario	12
C 4 2	Carcinogenic Intakes Institutional Controls Scenario	13
C 4 3	Carcinogenic Intakes Remediation Scenario	14
C 4 4	Noncarcinogenic Intakes No Action Scenario	15
C 4 5	Noncarcinogenic Intakes Institutional Controls Scenario	16
C 4 6	Noncarcinogenic Intakes Remediation Scenario	17
C 5 1	Chemical Specific Constants	19
C 6 1	Carcinogenic Risk No Action Scenario	29
C 6 2	Carcinogenic Risks Institutional Control Scenario	30
C 6 3	Carcinogenic Risks, Remediation Scenario	31
C 6 4	Noncarcinogenic HIs No Action Scenario	32
C 6 5	Noncarcinogenic HIs Institutional Controls Scenario	33
C 6 6	Noncarcinogenic HIs Remediation Scenario	34
C 7 1	Selected Qualitative Uncertainty Factors	39

ACRONYMS

1 1 DCE	1 1 dichloroethene
1 1 1 TCA	1 1 1 trichloroethane
ATSDR	Agency for Toxic Substances and Disease Registry
BRA	Baseline Risk Assessment
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CCl ₄	carbon tetrachloride
CNS	central nervous system
DOE	Department of Energy
EE	Ecological Evaluation
EPA	Environmental Protection Agency
FS	Feasibility Study
HI	hazard indices
HQ	hazard quotient
NOAEL	no observed adverse effect level
OU1	Operable Unit No 1
PCE	tetrachloroethene
PHE	Public Health Evaluation
PRG	preliminary remediation goal
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RFETS	Rocky Flats Environmental Technology Site
RFI/RI	RCRA Facility Investigation/Remedial Investigation
SFs	slope factors
VOCs	volatile organic compounds

C 1 0 INTRODUCTION

The Phase III Resource Conservation and Recovery Act (RCRA) Facility Investigation/Comprehensive Environmental Response Compensation and Liability Act (CERCLA) Remedial Investigation (RFI/RI) at Operable Unit No 1 (OU1) 881 Hillside Area at the Rocky Flats Environmental Technology Site (RFETS) includes a Baseline Risk Assessment (BRA) The BRA is comprised of an Ecological Evaluation (EE) and a Public Health Evaluation (PHE) The results of the complete OU1 PHE are presented in Volume X Appendix F of the Final Phase III RFI/RI dated June 1994 [Department of Energy (DOE) 1994a]

This risk assessment performed for the OU1 Feasibility Study (FS) is intended to calculate and document the human health risks associated with OU1 assuming that specified remedial actions are incorporated at the site This risk assessment considered the dominating carcinogenic risks noncarcinogenic hazards associated contaminants pathways and receptors determined in the PHE and calculated risk based on contaminant levels at the site due to incorporation of specified remedial actions The three remedial action alternatives include no action continued use of the french drain and extraction well (institutional controls) and remediating the contamination at the source (remediation)

C 2 0 EXPOSURE PATHWAYS, AND RECEPTORS OF CONCERN

This section discusses the potential release and transport of chemicals from OU1 This section also discusses the potential receptors of concern and the exposure pathways by which these receptors may be exposed to site contaminants

C 2 1 Exposure Pathways

An exposure pathway describes a specific environmental pathway that can expose an individual to contaminants that are onsite or originate from a site Five elements that must be present for an exposure pathway to be complete

- Source of chemicals
- Mechanism of chemical release
- Environmental transport medium
- Exposure point
- Human intake route

An incomplete pathway means that no human exposure can occur An exposure pathway is considered to be potentially complete and relevant if there are potential chemical release and transport mechanisms and receptors identified for that exposure pathway

An exposure route is the pathway through which a contaminant enters or impacts an organism There are four basic human exposure routes

- Dermal absorption through contact with soil, surface water or groundwater
- Inhalation of volatile organic compounds (VOCs) or airborne particulates
- Ingestion of soil surface water groundwater or food
- External irradiation if radionuclides are present

As documented in the PHE the pathways that dominated the human health risk are associated with groundwater contamination Therefore the pathways considered in this risk assessment

will only consider groundwater contamination associated with the potential remedial actions

C 2 2 Receptors of Concern

Receptors that were quantitatively evaluated in the PHE were

- Current offsite residents
- Future onsite residents
- Current onsite workers
- Future onsite workers
- Future onsite ecological researcher

Of these potential receptors only the future onsite residents and the future onsite workers could be significantly exposed to contaminants in the groundwater. These two receptors and potential scenarios are conservative since neither receptor could be exposed until the RFETS has been released for unrestricted use. The remaining receptors evaluated in the PHE do not have significant exposure to groundwater and therefore were not evaluated in this risk assessment.

Although onsite residences are not consistent with future land use plans, a hypothetical future onsite resident exposure scenario is evaluated in this risk assessment. The future onsite resident is assumed to live within the OU1 study area boundary at the Woman Creek location. To use the most conservative scenario for direct ingestion of groundwater, one of the future onsite resident scenarios assumes that an adequate well water supply exists.

A future onsite worker, assumed to be an office worker, is also quantitatively evaluated in this risk assessment. The setting for the office worker is likely to have extensive paved areas and well maintained landscaping. It is assumed that municipal water would be supplied to the office building and therefore the future office worker will not directly access OU1 groundwater.

C 2 2 1 Future Onsite Resident

Contaminants that volatilize from site groundwater and are released to indoor air through the

house foundation represent a potentially complete inhalation pathway to future onsite residents. Assuming that site groundwater is used within the household, inhalation of VOCs from indoor water use represents another potentially complete inhalation pathway. Inhalation of outdoor VOCs is considered insignificant due to expected dispersal and dilution of the VOCs.

Assuming that site groundwater will be used within the future onsite residential household, direct ingestion of groundwater contamination represents a potentially complete pathway. Future onsite residents also could physically contact contaminated groundwater. Therefore, dermal absorption of contaminants from contact with contaminated groundwater represents a potentially complete pathway.

The location of the groundwater contamination for the future onsite resident is assumed to be Woman Creek.

C 2 2 2 Future Onsite Office Worker

Since the municipal water, not groundwater, will be used in an office building, no direct exposure to groundwater is anticipated for the future onsite worker. The only remaining exposure pathway is volatilization of contaminants from site groundwater and release to indoor air through the office building foundation. The inhalation pathway is then potentially complete for the future onsite office worker. Similar to the future onsite resident scenario, the inhalation of outdoor VOCs is considered incomplete due to expected dispersal and dilution of the VOCs. As with the future onsite resident, the location of the contamination for the future onsite office worker is assumed to be Woman Creek.

C 3 0 CONTAMINANTS OF CONCERN

This section identifies the contaminants of concern and the contaminant concentrations used in the risk calculations

C 3 1 Contaminants Identified

The OU1 PHE (DOE 1994a) identified the future onsite adult resident receptor as having the highest potential risk values for the following contaminants

- 1 1 Dichloroethene (1 1 DCE)
- Carbon tetrachloride (CCl₄)
- Tetrachloroethene also known as perchloroethylene (PCE)

These risks were calculated assuming adequate groundwater present and available for receptor use The total risk values in the PHE for 1 1 DCE CCL₄ and PCE respectively are 3 8E 2 2 5E 3 and 1 1E 3 with the dominating pathway being ingestion of groundwater for all three contaminants

The contaminants with the highest calculated noncarcinogenic hazard indices (HI) in the PHE for the future onsite adult receptor assuming use of groundwater also include 1 1 DCE CCL₄ and PCE In addition to these three contaminants 1 1 1 trichloroethane (1 1 1 TCA) has an elevated HI These four contaminants also yielded the highest HIs for the future onsite residential child receptor and are of the same order of magnitude as the adult receptor

The three most dominating pathways for these contaminants are ingestion of groundwater inhalation of volatiles and dermal contact with groundwater These pathways are all driven by groundwater contamination and therefore this risk assessment focuses on groundwater associated pathways only Groundwater modeling results are used to derive concentrations of contamination in groundwater at Woman Creek By comparing initial modeling results with

respective contaminant specific preliminary remediation goals (PRGs) for RFETS (DOE 1994b) these contaminants were deemed appropriate to use in this risk calculation Detailed groundwater modeling results (refer to Appendix B) for these contaminants are used to calculate carcinogenic risk and noncarcinogenic HIs

C 3 2 Concentrations of Contaminants Identified

Groundwater modeling was used to calculate the expected contamination in groundwater at various locations downgradient of IHSS 119 1 The concentrations were modeled to include the specific remediation scenarios starting in 1969 and continuing in time steps The three scenarios were modeled out to the year 2029 Concentration averages were calculated for each contaminant at the French Drain and at Women Creek For the no action and institutional controls scenario 30 year averages were calculated For the remediation scenario concentration averages were taken beginning in 2008 after completion of remediation

The calculated groundwater concentrations were then used in the Johnson and Ettinger (1991) soil gas model which considers chemical specific parameters such as Henry s law constant and air diffusion coefficients to calculate a vapor concentration inside a building refer to the PHE for further details To calculate the concentration in indoor air from groundwater use the conservatively modeled groundwater concentrations were multiplied by the volatilization fraction of 0 065 mg/m³ air per mg/l water This conservative approach is consistent with Andelman (1990) and is discussed further in the PHE The concentrations of PCE and associated scenarios are summarized in Table C 3 1

Table C 3 1
Contaminant Concentrations

Contaminant	French Drain			Woman Creek		
	Indoor Air Volatiles Diffusing through the Foundation (mg/m ³)	Groundwater (mg/L)	Indoor Air from Groundwater Use (mg/m ³)	Indoor Air Volatiles Diffusing through the Foundation (mg/m ³)	Groundwater (mg/L)	Indoor Air from Groundwater Use (mg/m ³)
No Action Scenario						
1 1 DCE	4 23E 10	2 21E-04	1 43E-05	5 28E 15	2 75E-09	1 79E 10
1 1 1 TCA	1 71E-07	3 61E-02	2 35E-03	3 85E 10	8 12E-05	5 28E-06
CCL ₄	9 98E 10	1 72E-03	1 12E-04	3 52E 13	6 08E-07	3 95E-08
PCE	2 55E-09	9 49E-03	6 17E-04	1 23E 11	4 56E-05	2 97E-06
Institutional Controls Scenario						
1 1 DCE	6 18E 13	3 22E-07	2 09E-08	1 09E 17	5 67E-12	3 68E 13
1 1 1 TCA	4 64E-09	9 78E-04	6 36E-05	2 83E 11	5 97E-06	3 88E-07
CCL ₄	1 02E-11	1 76E-05	1 15E-06	1 22E 14	2 10E-08	1 37E-09
PCE	4 64E-09	9 78E-04	6 36E-05	1 36E 12	5 05E-06	3 28E-07
Remediation Scenario						
1 1 DCE	8 79E-15	4 59E-09	2 98E 10	4 48E-17	2 34E 11	1 52E 12
1 1 1 TCA	7 65E-09	1 61E-03	1 05E-04	1 00E 10	2 11E-05	1 37E-06
CCL ₄	1 77E 11	3 06E-05	1 99E-06	9 54E 14	1 65E-07	1 07E-08
PCE	2 38E 10	8 85E-04	5 75E-05	4 61E 12	1 71E-05	1 11E-06

C 4 0 EXPOSURE ASSESSMENT AND INTAKE EQUATIONS

Pathway specific exposures or intakes are quantified through the use of intake equations exposure parameters, and exposure concentrations Intake equations are pathway specific while exposure parameters and exposure concentrations are scenario-specific and pathway specific Exposure concentrations for this risk assessment have been modeled using groundwater modeling techniques (Appendix B) The generalized intake equations associated with each pathway and the non chemical specific parameters that are used in the equations are presented in this section

C 4 1 Ingestion of Water

Equation 1 was used to calculate direct ingestion or intake of contaminated water The ingestion rate was adjusted in accordance with the scenario

$$\text{Intake (mg/kg/day)} = \frac{\text{CW} \times \text{IR} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}} \quad (1)$$

where

- CW = Chemical concentration in water (mg/liter)
- IR = Ingestion rate (liter/day)
- EF = Exposure frequency (days/year)
- ED = Exposure duration (years)
- BW = Body weight (kg)
- AT = Averaging time (period over which exposure is averaged in days)

The chemical concentration in water is a modeled value and the modeling techniques are described in the PHE (DOE 1994a) Some parameters vary between adult and child receptors such as ingestion rates exposure durations and body weights The adult and child ingestion rates are 2 liters and 1 liter per day respectively Exposure frequency for residential receptors is 350 days/year The exposure durations for adult and child receptors are 30 and 6 years respectively The adult and child body weights are 70 and 15 kilograms respectively The averaging time for a carcinogen is 25 550 days or 70 years

C 4 2 Dermal Contact With Water

The future onsite resident is the only receptor that potentially can contact contaminated groundwater. Equation 2 was used to calculate the absorbed dose or intake of the contaminant through the skin. This equation calculates the actual absorbed dose, not the amount of chemical that comes in contact with the skin.

$$\text{Absorbed Dose (mg/kg/day)} = \frac{\text{CW} \times \text{SA} \times \text{PC} \times \text{ET} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}} \quad (2)$$

where

- CW = Chemical concentration in water (mg/liter)
- SA = Skin surface area available for contact (cm²)
- PC = Chemical specific dermal permeability constant (cm/hr)
- ET = Exposure time (hours/day)
- EF = Exposure frequency (days/year)
- ED = Exposure duration (years)
- CF = Volumetric conversion factor for water (1 liter/1000 cm³)
- BW = Body weight (kg)
- AT = Averaging time (period over which exposure is averaged in days)

The chemical concentration in water is a modeled value as described in the PHE. Some parameters vary between adult and child receptors, such as skin surface areas, exposure durations, and body weights. The adult and child skin surface areas are 23,200 cm² and 9,180 cm², respectively. The dermal permeability constants are chemical specific and their origination is discussed in the PHE. Adult and child exposure times for dermal contact with groundwater are 0.2 hours/day. Exposure frequency for a residential adult and child is 350 days/year. Adult and child exposure durations are 30 and 6 years, respectively. The volumetric conversion factor for water is 0.001 liters/cm³. Adult and child body weights are 70 and 15 kilograms, respectively. The averaging time for a carcinogen is 25,550 days or 70 years.

C 4 3 Inhalation of Airborne Contaminants

Exposure scenarios involving the residential adult residential child and office worker include intake of airborne contaminants. The contaminants are in the vapor phase and originate from groundwater contaminants volatilizing and diffusing through either a home foundation or office building foundation as applicable. Assuming well water is used within the home the residential receptor can also inhale contaminants volatilized during in home water use. Dermal absorption of vapor phase contaminants is considered to be a negligible portion of inhalation intakes and, therefore, is disregarded in accordance with Risk Assessment Guidance for Superfund (RAGS) Supplemental Guidance [Environmental Protection Agency (EPA) 1991a]. Equation 3 was used to calculate inhalation intakes for residential and office worker receptors.

$$\text{Intake (mg/kg/day)} = \frac{\text{CA} \times \text{IR} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}} \quad (3)$$

where

- CA = Contaminant concentration in air (mg/m³)
- IR = Inhalation rate (m³/day)
- EF = Exposure frequency (days/year)
- ED = Exposure duration (years)
- BW = Body weight (kg)
- AT = Averaging time (period over which exposure is averaged in days)

Both residential and office worker receptors have the potential to inhale volatilized contamination that has diffused through the foundation of either a home or an office building as applicable. It is assumed that groundwater would not service onsite office buildings therefore only a residential receptor could inhale volatilized contamination due to indoor water use. The chemical concentrations in indoor air (volatilized through a foundation and volatilized due to indoor water use) are modeled values as described in the PHE. Some parameters vary between the onsite office worker adult and child receptors such as inhalation rates exposure frequencies exposure durations body weights and averaging times. The inhalation rate is 15 m³/day for a residential adult (assuming indoor activities) and 20 m³/day for both a residential child and office worker. The exposure frequency is 350 days/year for a residential adult and

child and 250 days/year for an office worker. The exposure duration is 30 years for a residential adult, 6 years for a residential child, and 25 years for an office worker. The body weight is 70 kilograms for a residential adult and office worker, and 15 kilograms for a residential child.

C 4 4 Contaminant Intakes

The intake equations discussed use the nonchemical specific parameters, chemical specific parameters, chemical concentrations, and appropriate scenarios to calculate respective chemical intakes. Tables C 4 1 through C 4 6 summarize the carcinogenic and noncarcinogenic intakes by scenario, receptor, and pathway.

**Table C 4-1
Carcinogenic Intakes, No Action Scenario**

Contaminant	Inhalation of Volatiles Diffusing Through Foundation (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact with Groundwater (mg/kg/d)	Inhalation of Volatiles from Indoor use of Groundwater (mg/kg/d)
French Drain				
Future Onsite Resident With Water Adult				
CCl ₄	8.79E-11	2.02E-05	1.03E-06	9.86E-06
PCE	2.25E-10	1.11E-04	1.24E-05	5.43E-05
1,1-DCE	3.72E-11	2.59E-06	9.61E-08	1.26E-06
Future Onsite Office Worker				
CCl ₄	6.98E-11	NAP	NAP	NAP
PCE	1.78E-10	NAP	NAP	NAP
1,1-DCE	2.96E-11	NAP	NAP	NAP
Woman Creek				
Future Onsite Resident With Water Adult				
CCl ₄	3.10E-14	7.14E-09	3.64E-10	3.48E-09
PCE	1.08E-12	5.36E-07	5.97E-08	2.61E-07
1,1-DCE	4.65E-16	3.23E-11	1.20E-12	1.58E-11
Future Onsite Office Worker				
CCl ₄	2.46E-14	NAP	NAP	NAP
PCE	8.58E-13	NAP	NAP	NAP
1,1-DCE	3.69E-16	NAP	NAP	NAP

NAP = Not Applicable Pathway

Table C 4-2
Carcinogenic Intakes, Institutional Controls Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact with Groundwater (mg/kg/d)	Inhalation of Volatiles from Indoor use of Groundwater (mg/kg/d)
French Drain				
Future Onsite resident With Water Adult				
CCl ₄	8 99E 13	2 07E-07	1 06E-08	1 01E-07
PCE	1 01E 11	5 01E-06	5 58E-07	2 44E-06
1 1 DCE	5 44E-14	3 78E-09	1 40E-10	1 84E-09
Future Onsite Office Worker				
CCl ₄	7 14E-13	NAP	NAP	NAP
PCE	8 03E-12	NAP	NAP	NAP
1 1 DCE	4 32E 14	NAP	NAP	NAP
Woman Creek				
Future Onsite resident With Water Adult				
CCl ₄	1 07E-15	2 47E-10	1 26E-11	1 20E-10
PCE	1 20E-13	5 93E-08	6 60E-09	2 89E-08
1 1 DCE	9 57E-19	6 66E 14	2 47E 15	3 24E 14
Future Onsite Office Worker				
CCl ₄	8 51E 16	NAP	NAP	NAP
PCE	9 49E-14	NAP	NAP	NAP
1 1 DCE	7 60E 19	NAP	NAP	NAP

NAP = Not Applicable Pathway

**Table C 4-3
Carcinogenic Intakes, Remediation Scenario**

Contaminant	Inhalation of Volatiles Diffusing Through Foundation (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact with Groundwater (mg/kg/d)	Inhalation of Volatiles from Indoor use of Groundwater (mg/kg/d)
French Drain				
Future Onsite Resident With Water Adult				
CCl ₄	1 56E 12	3 60E-07	1 84E-08	1 75E-07
PCE	2 10E-11	1 04E-05	1 16E-06	5 06E-06
1 1 DCE	7 74E 16	5 39E-11	2 00E 12	2 63E 11
Future Onsite Office Worker				
CCl ₄	1 24E 12	NAP	NAP	NAP
PCE	1 66E-11	NAP	NAP	NAP
1 1 DCE	6 15E 16	NAP	NAP	NAP
Woman Creek				
Future Onsite Resident With Water Adult				
CCl ₄	8 40E 15	1 93E-09	9 87E 11	9 43E 10
PCE	4 06E 13	2 01E-07	2 24E-08	9 80E-08
1 1 DCE	3 94E 18	2 74E 13	1 02E-14	1 34E 13
Future Onsite Office Worker				
CCl ₄	6 67E 15	NAP	NAP	NAP
PCE	3 22E-13	NAP	NAP	NAP
1 1 DCE	3 13E 18	NAP	NAP	NAP

NAP = Not Applicable Pathway

Table C 4-4
Noncarcinogenic Intakes, No Action Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact with Groundwater (mg/kg/d)	Inhalation of Volatiles from Indoor use of Groundwater (mg/kg/d)
French Drain				
Future Onsite Resident With Water Adult				
CCl ₄	NA	5 90E-05	3 01E-06	NA
PCE	NA	3 25E-04	3 62E-05	NA
1 1 DCE	NA	7 55E-06	2 80E-07	NA
1 1 1 TCA	4 40E-08	1 24E-03	4 88E-05	6 03E-04
Future Onsite Resident With Water Child				
CCl ₄	NA	1 10E-04	4 45E-06	NA
PCE	NA	6 06E-04	5 34E-05	NA
1 1 DCE	NA	1 41E-05	4 14E-07	NA
1 1 1 TCA	2 19E-07	2 31E-03	7 21E-05	3 00E-03
Future Onsite Office Worker				
CCl ₄	1 95E-10	NAP	NAP	NAP
PCE	4 99E 10	NAP	NAP	NAP
1 1 DCE	8 28E-11	NAP	NAP	NAP
1 1 1 TCA	3 35E-08	NAP	NAP	NAP
Woman Creek				
Future Onsite Resident With Water Adult				
CCI	NA	2 08E-08	1 06E-09	NA
PCE	NA	1 56E-06	1 74E-07	NA
1 1 DCE	NA	9 43E 11	3 50E 12	NA
1 1 1 TCA	9 89E 11	2 78E-06	1 10E-07	1 36E-06
Future Onsite Resident With Water Child				
CCl ₄	NA	3 89E-08	1 57E-09	NA
PCE	NA	2 92E-06	2 57E-07	NA
1 1 DCE	NA	1 76E 10	5 17E 12	NA
1 1 1 TCA	4 92E 10	5 19E-06	1 62E-07	6 75E-06
Future Onsite Office Worker				
CCI	6 89E 14	NAP	NAP	NAP
PCE	2 40E 12	NAP	NAP	NAP
1 1 DCE	1 03E 15	NAP	NAP	NAP
1 1 1 TCA	7 54E 11	NAP	NAP	NAP

NA = Not Available

NAP = Not Applicable Pathway

Table C 4-5
Noncarcinogenic Intakes, Institutional Controls Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact with Groundwater (mg/kg/d)	Inhalation of Volatiles from Indoor use of Groundwater (mg/kg/d)
French Drain				
Future Onsite Resident With Water Adult				
CCl ₄	NA	6 04E-07	3 08E-08	NA
PCE	NA	1 46E-05	1 63E-06	NA
1 1 DCE	NA	1 10E-08	4 10E 10	NA
1 1 1 TCA	1 19E-09	3 35E-05	1 32E-06	1 63E-05
Future Onsite Resident With Water Child				
CCl ₄	NA	1 13E-06	4 55E-08	NA
PCE	NA	2 73E-05	2 41E-06	NA
1 1 DCE	NA	2 06E-08	6 05E-10	NA
1 1 1 TCA	5 93E-09	6 25E-05	1 95E-06	8 13E-05
Future Onsite Office Worker				
CCl ₄	2 00E 12	NAP	NAP	NAP
PCE	2 25E 11	NAP	NAP	NAP
1 1 DCE	1 21E 13	NAP	NAP	NAP
1 1 1 TCA	9 08E 10	NAP	NAP	NAP
Woman Creek				
Future Onsite Resident With Water Adult				
CCl ₄	NA	7 20E-10	3 67E 11	NA
PCE	NA	1 73E-07	1 93E-08	NA
1 1 DCE	NA	1 94E 13	7 21E 15	NA
1 1 1 TCA	7 28E 12	2 05E-07	8 07E-09	9 97E-08
Future Onsite Resident With Water Child				
CCl ₄	NA	1 34E-09	5 43E 11	NA
PCE	NA	3 23E-07	2 84E-08	NA
1 1 DCE	NA	3 62E 13	1 06E 14	NA
1 1 1 TCA	3 62E 11	3 82E-07	1 19E-08	4 96E-07
Future Onsite Office Worker				
CCl ₄	2 38E 15	NAP	NAP	NAP
PCE	2 66E 13	NAP	NAP	NAP
1 1 DCE	2 13E-18	NAP	NAP	NAP
1 1 1 TCA	5 54E 12	NAP	NAP	NAP

NA = Not Available

NAP = Not Applicable Pathway

Table C 4-6
Noncarcinogenic Intakes, Remediation Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact with Groundwater (mg/kg/d)	Inhalation of Volatiles from Indoor use of Groundwater (mg/kg/d)
French Dram				
Future Onsite Resident With Water Adult				
CCl ₄	NA	1 05E-06	5 36E-08	NA
PCE	NA	3 03E-05	3 37E-06	NA
1 1 DCE	NA	1 57E 10	5 83E-12	NA
1 1 1 TCA	1 96E-09	5 53E-05	2 18E-06	2 69E-05
Future Onsite Resident With Water Child				
CCl ₄	NA	1 96E-06	7 91E-08	NA
PCE	NA	5 66E-05	4 98E-06	NA
1 1 DCE	NA	2 93E-10	8 61E 12	NA
1 1 1 TCA	9 78E-09	1 03E-04	3 22E-06	1 34E-04
Future Onsite Office Worker				
CCl ₄	3 47E-12	NAP	NAP	NAP
PCE	4 66E 11	NAP	NAP	NAP
1 1 DCE	1 72E 15	NAP	NAP	NAP
1 1 1 TCA	1 50E-09	NAP	NAP	NAP
Woman Creek				
Future Onsite Resident With Water Adult				
CCl ₄	NA	5 64E-09	2 88E 10	NA
PCE	NA	5 86E-07	6 53E-08	NA
1 1 DCE	NA	8 00E-13	2 97E 14	NA
1 1 1 TCA	2 57E 11	7 23E-07	2 85E-08	3 53E-07
Future Onsite Resident With Water Child				
CCl ₄	NA	1 05E-08	4 25E 10	NA
PCE	NA	1 09E-06	9 64E-08	NA
1 1 DCE	NA	1 49E 12	4 39E 14	NA
1 1 1 TCA	1 28E 10	1 35E-06	4 21E-08	1 76E-06
Future Onsite Office Worker				
CCl ₄	1 87E 14	NAP	NAP	NAP
PCE	9 01E 13	NAP	NAP	NAP
1 1 DCE	8 76E 18	NAP	NAP	NAP
1 1 1 TCA	1 96E 11	NAP	NAP	NAP

NA = Not Available

NAP = Not Applicable Pathway

C 5 0 TOXICITY ASSESSMENT

This section provides the toxicity constants used for risk characterization purposes and summarizes toxicological information. Specific derivation of toxicity constants and respective sources is discussed in the PHE. For this risk assessment, toxicity information is summarized for two categories of potential effects: noncarcinogenic and carcinogenic effects. These two categories were selected because of the slightly differing methodologies for estimating potential health risks associated with exposures to carcinogens and noncarcinogens. Toxicity information is provided for the four contaminants of concern:

- 1,1 DCE
- 1,1,1 TCA
- CCl₄
- PCE

Table C 5 1 also summarizes chemical specific constants for each of these contaminants.

C 5 1 1,1 DCE

Volatilization and subsequent photo-oxidation in the atmosphere are the primary transport and fate process for 1,1 DCE. The available information also indicates that sorption, bioaccumulation, and degradation of 1,1 DCE are possible, albeit at lower rates and are not of environmental significance.

Studies on the general toxicity and possible carcinogenicity of 1,1 DCE are limited. Oral LD50 of 1,1 DCE in rat is 1,500 mg/kg. Exposure to high concentrations is often associated with disturbances of the central nervous system. Chronic exposure to low doses of 1,1 DCE has been shown to produce hepatic and renal toxicity. However, 1,1 DCE does not produce embryotoxicity and teratogenic effects in experimental animals.

Table C 5 1
Chemical Specific Constants

Analyte	Weight of Evidence	SF Ingestion (mg/kg day) ¹	SF Inhalation (mg/kg day) ¹	Target System	RfD Ingestion (mg/kg day)	RfD Inhalation (mg/kg day)	Dermal Permeability (cm/hr)
1 1 DCE	C	6 00E-01	1 75E-01	Hepatic	9 00E-03	NA	1 60E-02
1 1 1 TCA	D	NA	NA	CNS	9 00E-02	3 00E+00	1 70E-02
CCl ₄	B2	1 30E-01	5 25E-02	Hepatic	7 00E-04	NA	2 20E-02
PCE	B2	5 20E-02	2 03E-03	Hepatic	1 00E-02	NA	4 80E-02

The results of the studies on the carcinogenic effects of 1,1-DCE are inconclusive. However, 1,1-DCE has been shown to be mutagenic in several bacterial assays.

For 1,1-DCE, the oral reference dose (RfD) is 9.00×10^{-3} mg/kg/day and the oral and inhalation slope factors (SFs) are 6.00×10^{-1} and 1.75×10^{-1} (mg/kg/day)¹ respectively (Table C-5.1).

C-5.2 1,1,1-TCA

1,1,1-TCA is used as a solvent for cleaning precision instruments, for metal degreasing, as aerosol propellants, as a pesticide, and in textile processing.

1,1,1-TCA has a low toxicity profile (oral LD₅₀ in rats is 11,000 mg/kg). Both in humans and animals, high concentrations of 1,1,1-TCA causes disturbances of the central nervous system characterized by such symptoms as depression, imbalance in equilibrium, and temporary reversible loss of coordination. Other effects including cardiovascular effects such as hypotension, premature ventricular contractions, and arrhythmia have been reported. Effects such as irritation of the skin, mucous membranes, and eye as a result of exposure to 1,1,1-TCA has been reported (EPA, 1985).

Torkelson et al. (1958) exposed groups of rats, rabbits, guinea pigs, and monkeys to 1,1,1-TCA vapor at concentrations of 500, 1000, 2000, or 10,000 ppm. From these studies, it was determined that the female guinea pig was the most sensitive species of those tested. At 500 ppm, groups of eight male and eight female guinea pigs showed no evidence of adverse effects compared with unexposed and air-exposed controls after exposure for 7 hours/day, 5 days/week for 6 months. Groups of five female guinea pigs exposed to 1000 ppm 1,1,1-TCA vapor 3 hours/day, 5 days/week for 3 months had fatty changes in the liver and statistically significant increased liver weights. Thus, this study defined a NOAEL of 500 ppm (2730 mg/m³) in guinea pigs.

In a similar study (Adams et al., 1950), groups of guinea pigs of 6-10 were exposed to

1 1 1 TCA (650 ppm) vapor 7 hours/day, 5 days week for 2 to 3 months These animals exhibited a slight depression in weight gain compared with both air exposed and unexposed controls thereby establishing a LOAEL of 650 ppm (3550 mg/m³) in guinea pigs

On the basis of the existing inadequate animal data and absence of human carcinogenicity data 1 1 1 TCA is not classifiable as to human carcinogenicity (EPA weight of evidence classification D) There are no reported human data and animal studies (one lifetime gavage and one intermediate term inhalation) have not demonstrated carcinogenicity Technical grade 1 1 1 TCA has been shown to be weakly mutagenic although the contaminant 1 4 dioxane a known animal carcinogen may be responsible for this response

C 5 3 CCl₄

CCl₄ is used in the preparation of refrigerants aerosols and propellants the preparation of chlorofluoromethanes the production of semiconductors dry cleaning operations veterinary medicine and organic synthesis It is also used as an agricultural fumigant a solvent for fats oils and rubber and an industrial extractant

The effects of CCl₄ were studied by Lamson and Minot (1928) in patients receiving CCl₄ and magnesium sulfate orally as a treatment for hookworms The authors reported the treatment of thousands of patients with a single dose of 2 5 15 ml of CCl₄ without any adverse effects One man was reported to have safely ingested 40 ml of CCl₄ However an extremely small population of adults died after receiving 1 5 ml of CCl₄ and doses of 0 18 0 92 ml were reported to be fatal to children

The toxic effect of CCl₄ are potentiated by both the habitual and occasional ingestion of alcohol (EPA 1991b) Pretreatment of laboratory animals with ethanol methanol or isopropanol increases the susceptibility of the liver to CCl₄ Protective effects against CCl₄ induced lipid peroxidation are exhibited by vitamin E selenium and methionine Very obese or undernourished persons or those suffering from pulmonary diseases gastric ulcers or a tendency

to vomiting liver or kidney diseases diabetes or glandular disturbances are especially sensitive to the toxic effect of CCl_4 (Von Oettingen 1964)

Stewart et al (1961) reported the toxic effects of experimental exposure of human volunteers to CCl_4 vapor Healthy males 30 59 years of age were exposed to concentrations of 63 69 and 309 mg/m^3 of CCl_4 in an exposure chamber for 180 minutes at the two lower doses or 70 minutes at the highest dose One of six subjects exposed to the highest concentration experienced had an increased level of urinary urobilinogen 7 days after exposure In addition two out of four subjects exposed to the highest concentration and monitored for serum iron showed a decrease within 48 hours after exposure

Little data are available concerning the teratogenic effects of CCl_4 Schwetz et al (1974) found CCl_4 to be slightly embryotoxic and to a certain degree retarded fetal development when administered to rats at 300 or 1000 mg/l for 7 hours/day on gestation days 6-15

Cases of chronic poisoning have been reported by Von Oettingen (1964) and others The clinical picture of chronic CCl_4 poisoning is much less characteristic than that of acute poisoning Patients suffering from this condition may complain of fatigue lassitude giddiness anxiety and headache They suffer from paresthesia and muscular twitchings and show increased reflex excitability They may be moderately jaundiced, have a tendency to hypoglycemia and biopsy specimens of the liver may show fatty infiltration Patients complain of lack of appetite nausea and occasionally of diarrhea In some instances the blood pressure is lowered and is accompanied by pain in the cardiac region and mild anemia Other patients have developed pain in the kidney region dysuria and slight nocturia and have had urine containing small amounts of albumin and a few red blood cells Burning of the eyes and in a few instances blurred vision are frequent complaints of those exposed If these symptoms are not pronounced or of long standing recovery usually takes place upon discontinuation of the exposure if the proper treatment is received (Von Oettingen 1964)

Reports on pathological changes in fatalities from CCl_4 poisoning are generally limited to

findings in the liver and kidneys. The brain and lungs may be edematous. The intestines may be hyperemic and covered with numerous petechial hemorrhages and the spleen may be enlarged and hyperemic. Occasionally the adrenal glands may show degenerative changes of the cortex and the heart may undergo toxic myocarditis (Von Oettingen 1964).

There have been three case reports of liver tumors developing after CCl_4 exposure. Several studies of workers who may have used CCl_4 have suggested that these workers may have an excess risk of cancer. CCl_4 has been classified by the EPA as a probable human carcinogen (EPA weight of evidence classification B2) based on carcinogenicity in rats, mice and hamsters producing hepatocellular carcinomas in all three of these species (EPA 1991c).

C 5 4 PCE

PCE has widespread use in the dry cleaning and textile industries. It is also used in the cold cleaning and vapor degreasing of metals, as a chemical intermediate in the synthesis of fluorocarbons, as a component of aerosol laundry treatment products, as a solvent for silicones, as the insulating fluid and cooling gas in electrical transformers, and in typewriter correction fluid. PCE is not known to occur naturally, but contributes to water pollution through leaching from vinyl liners in asbestos-cement water pipelines and as wastewater from metal finishing laundries, aluminum forming, organic chemical/plastics manufacturing, and municipal treatment plants. Air contamination is the result of emissions and vaporization losses from dry cleaning and industrial metal cleaning (ATSDR 1992).

The effects discussed below are due to occupational exposure levels which are much higher than the expected environmental levels. Primarily, exposure occurs through inhalation of contaminated air or ingestion of contaminated water. PCE can cause lightheadedness, dizziness, euphoria, blindness, cardiac arrhythmias, hypotension, cyanosis, respiratory depression, pulmonary hemorrhages, and central nervous system (CNS) depression in acute dosages. When chronically dosed, trigeminal nerve impairment, liver injury, and chapped skin can occur. PCE is metabolized and excreted very slowly. Individuals with diseases of the heart, liver, kidneys,

and lungs are the most vulnerable to PCE poisoning. It has also been known to cause jaundice in newborns from PCE excretion in the breast milk [Agency for Toxic Substances and Disease Registry (ATSDR) 1992]

Historically few acute or chronic industrial toxicity problems have arisen from the use of this solvent although researchers have reported both hepatotoxicity and CNS effects. Ingested or inhaled PCE is mostly excreted by the lungs. The metabolism of PCE is very slow; a very low percentage is excreted in the urine as metabolites. Currently no inhalation RfD is available for PCE. Oral RfDs have been calculated based on research with rodents. Primary effects associated with PCE exposure include liver and kidney damage and CNS depression. The oral RfD for chronic exposures is 1×10^{-2} mg/kg/day with an uncertainty factor of 1000. There is medium confidence in this RfD because no one study combined the features required for deriving a high confidence RfD. Confidence in the principle study is low because it lacked complete histopathological examination at the no observed adverse effect level (NOAEL) and corroborative studies on its teratogenic and reproductive impacts are lacking (EPA 1994).

PCE is listed as a probable group B2 carcinogen in IRIS, has an oral SF of 5×10^{-2} and an inhalation SF of 2×10^{-3} . This classification was based on studies performed on rodents where inhalation produced both leukemia and tumors of the liver. PCE is for the most part nonmutagenic and has not been shown to cause reproductive toxicity.

C 6 0 RISK CHARACTERIZATION

Risk characterization involves estimating the magnitude of potential adverse effects summarizing the nature of the threats to public health and considering the nature and weight of evidence supporting these risk estimates and the degree of uncertainty surrounding the estimates. Specifically risk characterization involves combining the results of the exposure and toxicity assessments to provide numerical estimates of health risk. These estimates are comparisons of exposure levels with appropriate RfDs or estimates of the lifetime cancer risk with a given intake.

Generally to quantify the health risks the intakes are first calculated as identified in Section C 4 0 for each applicable scenario. The intakes were calculated from the concentrations discussed in Section C 3 2 and the methodology documented in RAGS (EPA 1989). The specific intakes, calculated in Section C 4, were then compared to the applicable chemical specific toxicological data presented in Section C 5 to determine the health risk.

The health risks from the contaminants were calculated to determine potential carcinogenic and noncarcinogenic effects as discussed in Sections C 6 1 and C 6-2 respectively.

C 6 1 Risk and Hazard Quotient Calculation

Potential carcinogenic risks are expressed as an estimated probability of an individual developing cancer from lifetime exposure to the carcinogen. This probability is based on projected intakes and chemical specific dose response data called cancer slope factors (SFs). Cancer SFs and the estimated daily intake of a compound averaged over a lifetime of exposure is used to estimate the incremental risk that an individual exposed to that compound may develop cancer. Potential carcinogenic risks are estimated from the following equation:

$$\text{Risk} = \text{Intake} \times \text{SF} \quad (4)$$

where

Risk	=	Potential lifetime excess cancer risk (unitless)
SF	=	Slope factor for chemicals (mg/kg/day) ¹
Intake	=	Chemical intake (mg/kg/day)

Potential health effects of chronic exposure to noncarcinogenic compounds is assessed by calculating a hazard quotient (HQ) which is derived by dividing the estimated daily intake by a chemical specific RfD as shown in the following equation

$$HQ = \text{Intake/RfD} \quad (5)$$

where

HQ	=	Noncancer hazard quotient (unitless)
Intake	=	Chemical intake (mg/kg/day)
RfD	=	Reference dose (mg/kg/day)

A HQ greater than 1.0 indicates that exposure to that contaminant (at the concentrations and for the duration and frequencies of exposure estimated in the exposure assessment) may cause adverse health effects in exposed populations. However, the level of concern associated with exposure to noncarcinogenic compounds does not increase linearly as HQ values exceed 1.0. In other words, HQ values do not represent a probability or a percentage. For example, an HQ of 10 does not indicate that adverse health effects are 10 times more likely to occur than an HQ value of 1.0, but that potential adverse health effects are of greater concern.

C 6.2 Carcinogenic Effects

Carcinogenic risks from exposure to each contaminant were calculated and summed for a future onsite resident using groundwater, using public water, and for a future onsite office worker using public water. The source of contamination considered (1) maintaining the current groundwater contamination level and removing the french drain and extraction well, (2) maintaining the current groundwater contamination level and continuing the french drain and extraction well operations, and (3) remediating the contamination source and removing the

french drain and extraction well. These receptors and scenarios considered contamination at the French Drain and at Woman Creek. Tables C 6 1 through C 6-3 summarize the results of the risk calculations by scenario, receptor, and pathway.

For all three scenarios, the highest carcinogenic risks at the French Drain and at Woman Creek are associated with the future onsite resident. The risks for the future office worker are negligible (in the 10^{-12} to 10^{-16} range).

The scenario that yielded the maximum calculated carcinogenic risks was the no action scenario. The total calculated risk for the future onsite resident with this exposure is 1.17×10^{-5} with the dominating pathway of ingestion of groundwater with a risk of 9.97×10^{-6} (see Table C 6 1). The risk from the next dominant pathway, inhalation of volatiles from indoor use of groundwater, is 8.44×10^{-7} .

The scenario with the next highest calculated carcinogenic risk assumed remediation of the contamination and discontinuing the operation of the french drain and extraction well. The total calculated risk for the future on site resident with this exposure is 6.69×10^{-7} with the dominating pathway of ingestion of groundwater with a risk of 5.87×10^{-7} (see Table C 6 3).

The institutional controls scenario has the lowest calculated carcinogenic risks. The total calculated risk for the future on site resident with this exposure is 3.31×10^{-7} with the dominating pathway of ingestion of groundwater with a risk of 2.88×10^{-7} (see Table C 6 2). In all three scenarios, PCE is responsible for the highest risks.

C 6 3 Noncarcinogenic Effects

The receptors and pathways used to evaluate carcinogenic effects were also used to evaluate noncarcinogenic effects. The HIs for each contaminant are the summed HQs for each exposure pathway. If the HI exceeds unity, there may be a concern for potential health effects and the exposure should be evaluated more closely. Tables C 6 4 through C 6 6 summarize the results.

of the HQ and HIs calculations by scenario receptor and pathway

The calculation of HQs and respective HIs did not yield a significant noncarcinogenic hazard (i.e. did not approach unity). The highest HI is 2.59×10^{-1} for a future onsite child resident and the no action scenario (see Table C-6.4). The dominating pathway for this receptor is ingestion of groundwater with a HQ of 1.57×10^{-1} from CCl_4 . The remaining HIs ranged from 1.40×10^{-1} to 1.85×10^{-12} .

Table C 6-1
Carcinogenic Risks, No Action Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation	Ingestion of Groundwater	Dermal Contact with Groundwater	Inhalation of Volatiles from Indoor use of Groundwater	Total Risks by Contaminant	Total Risks from All Contaminants and Pathways
French Drain						
Future Onsite Resident With Water Adult						
CCl ₄	4 57E 12	2 63E-06	1 34E-07	5 13E-07	3 28E-06	1 17E-05
PCE	4 56E 13	5 79E-06	6 45E-07	1 10E-07	6 55E-06	
1 1 DCE	6 52E 12	1 55E-06	5 77E-08	2 21E-07	1 83E-06	
Future Onsite Office Worker						
CCl ₄	3 63E 12	NAP	NAP	NAP	3 63E 12	9 16E 12
PCE	3 62E 13	NAP	NAP	NAP	3 62E 13	
1 1 DCE	5 17E 12	NAP	NAP	NAP	5 17E 12	
Women Creek						
Future Onsite Resident With Water Adult						
CCl ₄	1 61E 15	9 28E 10	4 74E-11	1 81E 10	1 16E-09	3 27E-08
PCE	2 20E 15	2 79E-08	3 10E 09	5 30E 10	3 15E-08	
1 1 DCE	8 14E 17	1 94E 11	7 20E 13	2 76E 12	2 29E 11	
Future Onsite Office Worker						
CCl ₄	1 28E 15	NAP	NAP	NAP	1 28E 15	3 09E 15
PCE	1 74E 15	NAP	NAP	NAP	1 74E 15	
1 1 DCE	6 46E 17	NAP	NAP	NAP	6 46E 17	

NAP = Not applicable pathway

Table C 6-2
Carcinogenic Risks, Institutional Controls Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation	Ingestion of Groundwater	Dermal Contact with Groundwater	Inhalation of Volatiles from Indoor use of Groundwater	Total Risks by Contaminant	Total Risks from All Contaminants and Pathways
French Drain						
Future Onsite Resident With Water Adult						
CCl ₄	4 68E 14	2 69E-08	1 37E-09	5 25E-09	3 35E-08	3 31E-07
PCE	2 05E 14	2 61E-07	2 90E-08	4 96E-09	2 95E-07	
1 1 DCE	9 52E 15	2 27E-09	8 43E 11	3 23E 10	2 68E-09	
Future Onsite Office Worker						
CCl ₄	3 71E 14	NAP	NAP	NAP	3 71E 14	6 10E 14
PCE	1 63E 14	NAP	NAP	NAP	1 63E 14	
1 1 DCE	7 56E 15	NAP	NAP	NAP	7 56E 15	
Women Creek						
Future Onsite Resident With Water Adult						
CCl ₄	5 57E 17	3 21E 11	1 64E 12	6 26E 12	4 00E 11	3 52E-09
PCE	2 43E 16	3 08E-09	3 43E 10	5 87E 11	3 48E-09	
1 1 DCE	1 67E 19	3 99E 14	1 48E-15	5 68E 15	4 71E 14	
Future Onsite Office Worker						
CCl ₄	4 42E 17	NAP	NAP	NAP	4 42E 17	2 37E 16
PCE	1 93E 16	NAP	NAP	NAP	1 93E 16	
1 1 DCE	1 33E 19	NAP	NAP	NAP	1 33E 19	

NAP = Not applicable pathway

**Table C 6-3
Carcinogenic Risks, Remediation Scenario**

Contaminants	Inhalation of Volatiles Diffusing Through Foundation	Ingestion of Groundwater	Dermal Contact with Groundwater	Inhalation of Volatiles from Indoor use of Groundwater	Total Risks by Contaminant	Total Risks from All Contaminants and Pathways
French Drain						
Future Onsite Resident With Water Adult						
CCl ₄	8 13E 14	4 68E-08	2 39E-09	9 12E-09	5 83E-08	6 69E-07
PCE	4 26E 14	5 40E-07	6 02E-08	1 03E-08	6 11E-07	
1 1 DCE	1 36E 16	3 23E 11	1 20E-12	4 59E 12	3 81E 11	
Future Onsite Office Worker						
CCl ₄	6 45E 14	NAP	NAP	NAP	6 45E 14	9 84E 14
PCE	3 38E 14	NAP	NAP	NAP	3 38E 14	
1 1 DCE	1 08E 16	NAP	NAP	NAP	1 08E 16	
Women Creek						
Future Onsite Resident With Water Adult						
CCl ₄	4 37E 16	2 51E 10	1 28E 11	4 90E 11	3 13E 10	1 21E-08
PCE	8 23E 16	1 05E-08	1 16E-09	1 99E 10	1 18E-08	
1 1 DCE	6 90E 19	1 65E 13	6 11E 15	2 34E 14	1 94E 13	
Future Onsite Office Worker						
CCl ₄	3 47E 16	NAP	NAP	NAP	3 47E 16	1 00E 15
PCE	6 53E 16	NAP	NAP	NAP	6 53E 16	
1 1 DCE	5 48E-19	NAP	NAP	NAP	5 48E 19	

NAP = Not applicable pathway

Table C 6-4
Noncarcinogenic HIs, No Action Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation	Ingestion of Groundwater	Dermal Contact with Groundwater	Inhalation of Volatiles from Indoor use of Groundwater	Total HIs by Contaminant	Total Risks from All Contaminants and Pathways
French Drain						
Future Onsite Resident With Water Adult						
CCI	NA	8 43E-02	4 30E-03	NA	8 86E-02	1 40E-01
PCE	NA	3 25E-02	3 62E-03	NA	3 61E-02	
1 1 DCE	NA	8 39E-04	3 12E-05	NA	8 70E-04	
1 1 1 TCA	1 47E-08	1 38E-02	5 42E-04	2 01E-04	1 45E-02	
Future Onsite Resident With Water Child						
CCI	NA	1 57E-01	6 36E-03	NA	1 64E-01	2 59E-01
PCE	NA	6 06E-02	5 34E-03	NA	6 60E-02	
1 1 DCE	NA	1 57E-03	4 60E-05	NA	1 61E-03	
1 1 1 TCA	7 30E-08	2 57E-02	8 01E-04	1 00E-03	2 75E-02	
Future Onsite Office Worker						
CCI	NA	NAP	NAP	NAP	0 00E+00	1 12E-08
PCE	NA	NAP	NAP	NAP	0 00E+00	
1 1 DCE	NA	NAP	NAP	NAP	0 00E+00	
1 1 1 TCA	1 12E-08	NAP	NAP	NAP	1 12E-08	
Women Creek						
Future Onsite Resident With Water Adult						
CCI	NA	2 97E-05	1 52E-06	NA	3 13E-05	2 38E-04
PCE	NA	1 56E-04	1 74E-05	NA	1 74E-04	
1 1 DCE	NA	1 05E-08	3 89E-10	NA	1 09E-08	
1 1 1 TCA	3 30E-11	3 09E-05	1 22E-06	4 52E-07	3 26E-05	
Future Onsite Resident With Water Child						
CCI	NA	5 55E-05	2 24E-06	NA	5 78E-05	4 37E-04
PCE	NA	2 92E-04	2 57E-05	NA	3 17E-04	
1 1 DCE	NA	1 96E-08	5 75E-10	NA	2 01E-08	
1 1 1 TCA	1 64E-10	5 77E-05	1 80E-06	2 25E-06	6 18E-05	
Future Onsite Office Worker						
CCI	NA	NAP	NAP	NAP	0 00E+00	2 51E-11
PCE	NA	NAP	NAP	NAP	0 00E+00	
1 1 DCE	NA	NAP	NAP	NAP	0 00E+00	
1 1 1 TCA	2 51E-11	NAP	NAP	NAP	2 51E-11	

NA = Not available due to unavailability of tox city constant

NAP = Not applicable pathway

Table C 6-5
Noncarcinogenic HIs, Institutional Controls Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation	Ingestion of Groundwater	Dermal Contact with Groundwater	Inhalation of Volatiles from Indoor use of Groundwater	Total HIs by Contaminant	Total Risks from All Contaminants and Pathways
French Drain						
Future Onsite Resident With Water Adult						
CCI	NA	8 62E-04	4 40E-05	NA	9 06E-04	
PCE	NA	1 46E-03	1 63E-04	NA	1 63E-03	
1 1 DCE	NA	1 23E-06	4 55E-08	NA	1 27E-06	
1 1 1 TCA	3 97E-10	3 72E-04	1 47E-05	5 44E-08	3 92E-04	2 93E-03
Future Onsite Resident With Water Child						
CCI	NA	1 61E-03	6 50E-05	NA	1 67E-03	
PCE	NA	2 73E-03	2 41E-04	NA	2 97E-03	
1 1 DCE	NA	2 29E-06	6 72E-08	NA	2 36E-06	
1 1 1 TCA	1 98E-09	6 95E-04	2 17E-05	2 71E-05	7 44E-04	5 39E-03
Future Onsite Office Worker						
CCI	NA	NAP	NAP	NAP	0	
PCE	NA	NAP	NAP	NAP	0	
1 1 DCE	NA	NAP	NAP	NAP	0	
1 1 1 TCA	3 03E-10	NAP	NAP	NAP	3 03E-10	3 03E-10
Women Creek						
Future Onsite Resident With Water Adult						
CCI	NA	1 03E-06	5 25E-08	NA	1 08E-06	
PCE	NA	1 73E-05	1 93E-06	NA	1 92E-05	
1 1 DCE	NA	2 16E-11	8 01E-13	NA	2 24E-11	
1 1 1 TCA	2 43E-12	2 27E-06	8 97E-08	3 32E-08	2 40E-06	2 27E-05
Future Onsite Resident With Water Child						
CCI	NA	1 92E-06	7 75E-08	NA	2 00E-06	
PCE	NA	3 23E-05	2 84E-06	NA	3 51E-05	
1 1 DCE	NA	4 03E 11	1 18E-12	NA	4 14E-11	
1 1 1 TCA	1 21E-11	4 24E-06	1 32E-07	1 63E-07	4 54E-06	4 17E-05
Future Onsite Office Worker						
CCI	NA	NAP	NAP	NAP	0	
PCE	NA	NAP	NAP	NAP	0	
1 1 DCE	NA	NAP	NAP	NAP	0	
1 1 1 TCA	1 85E12	NAP	NAP	NAP	1 85E 12	1 850E-12

NA = Not available due to unava lability of toxicity constant
NAP = Not applicable pathway

Table C 6-6
Noncarcinogenic HIs, Remediation Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation	Ingestion of Groundwater	Dermal Contact with Groundwater	Inhalation of Volatiles from Indoor use of Groundwater	Total HIs by Contaminant	Total HIs from All Contaminants and Pathways
French Drain						
Future Onsite Resident With Water Adult						
CCI	NA	1 50E-03	7 65E-05	NA	1 58E-03	5 59E-03
PCE	NA	3 03E-03	3 37E-04	NA	3 37E-03	
1 1 DCE	NA	1 75E-08	6 48E-10	NA	1 81E-08	
1 1 1 TCA	6 55E-10	6 14E-04	2 42E-05	8 98E-06	6 47E-04	
Future Onsite Resident With Water Child						
CCI	NA	2 80E-03	1 13E-04	NA	2 91E-03	1 03E-02
PCE	NA	5 66E-03	4 98E-04	NA	6 15E-03	
1 1 DCE	NA	3 26E-08	9 57E-10	NA	3 35E-08	
1 1 1 TCA	3 26E-09	1 15E-03	3 58E-05	4 47E-05	1 23E-03	
Future Onsite Office Worker						
CCI	NA	NAP	NAP	NAP	0 00E+00	4 99E-10
PCE	NA	NAP	NAP	NAP	0 00E+00	
1 1 DCE	NA	NAP	NAP	NAP	0 00E+00	
1 1 1 TCA	4 99E-10	NAP	NAP	NAP	4 99E-10	
Women Creek						
Future Onsite Resident With Water Adult						
CCI	NA	8 06E-06	4 11E-07	NA	8 47E-06	8 21E-05
PCE	NA	5 86E-05	6 53E-06	NA	6 52E-05	
1 1 DCE	NA	8 89E-11	3 30E-12	NA	9 22E-11	
1 1 1 TCA	8 57E-12	8 04E-06	3 17E-07	1 18E-07	8 47E-06	
Future Onsite Resident With Water Child						
CCI	NA	1 50E-05	6 08E-07	NA	1 57E-05	1 51E-04
PCE	NA	1 09E-04	9 64E-06	NA	1 19E-04	
1 1 DCE	NA	1 66E-10	4 87E-12	NA	1 71E-10	
1 1 1 TCA	4 27E 11	1 50E-05	4 68E-07	5 85E-07	1 61E-05	
Future Onsite Office Worker						
CCI	NA	NAP	NAP	NAP	0 00E+00	6 53E-12
PCE	NA	NAP	NAP	NAP	0 00E+00	
1 1 DCE	NA	NAP	NAP	NAP	0 00E+00	
1 1 1 TCA	6 53E 12	NAP	NAP	NAP	6 53E-12	

NA = Not available due to unavailability of toxicity constant
NAP = Not applicable pathway

C 7 0 UNCERTAINTY ANALYSIS

Uncertainty analysis is an important component of the risk assessment process. According to the EPA *Guidance on Risk Characterization for Risk Managers and Risk Assessors*, point estimates of risk do not fully convey the range of information considered and used in developing the assessment (EPA 1992). To provide information about the uncertainties associated with the risk assessment, uncertainties were identified during the PHE process (DOE 1994a) and are presented in qualitative terms.

C 7 1 Sources of Uncertainty

There are four stages of analysis applied during the risk assessment process that can introduce uncertainties:

- Data Collection and Evaluation
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization

The uncertainty analysis characterizes the propagated uncertainty in public health risk assessments. These uncertainties are driven by uncertainty in the chemical monitoring data, the transport models used to estimate concentrations at receptor locations, receptor intake parameters, and the toxicity values used to characterize risk. Additionally, uncertainties are introduced in the risk assessment when exposures to several substances across multiple pathways are summed.

One approach to address the uncertainties is to use health protective assumptions. Health protective assumptions are those that systematically overstate the magnitude of health risks such that even with errors due to uncertainty in the methodology, actual health risks are expected to be less than those calculated. This process bounds the plausible upper limits of risk and facilitates an informed risk management decision.

C 7 1 1 Data Collection and Evaluation

Variability in observed concentrations is due to sampling design and implementation laboratory analysis seasonality contaminant level variation and natural variation

C 7 1 2 Exposure Assessment

The largest measure of uncertainty in the exposure assessment is associated with characterizing transport dispersion and transformation of COCs in the environment establishing exposure settings and deriving estimates of chronic intake The ultimate effect of this process is the generation of a range or distribution of estimates for intake at a given exposure point

C 7 1 3 Toxicity Assessment

Toxicity assessment is the process of characterizing the relationship between the dose or intake of a substance and the incidence of adverse effects in the exposed population Toxicity assessments evaluate results from studies with laboratory animals or from human epidemiological studies These evaluations are used to extrapolate high levels of exposure where adverse effects are known to occur to low levels of environmental exposures where effects can only be predicted based on statistical probabilities The results of these extrapolations are used to establish quantitative indicators of toxicity

C 7 1 4 Risk Characterization

The last step in the risk assessment is risk characterization This is the process of integrating the results of the exposure and toxicity assessments (i e comparing the estimates of intake with appropriate toxicological measures to determine the likelihood of adverse effects in potentially exposed populations) Similarly the propagated uncertainties defined throughout the uncertainty analysis process are combined and presented as part of the risk characterization to provide an overall uncertainty in the estimate of risk

C 7 2 Uncertainty in Human Intake Parameters

Inherent in the evaluation of modeled contaminant intake is the uncertainty in the values used to assign intakes. Uncertainty parameters of intake (such as ingestion rate) as well as parameters of demographics (residence time, length of work day, etc.) are evaluated quantitatively to the extent possible so that the uncertainty about the mean for those important variables is propagated through the analysis along with modeled concentrations and toxicity constants.

The selection of probability distributions as inputs to exposure and risk models is conducted according to guidance set forth in the *Exposure Factors Handbook* (EFH) (EPA, 1990).

In general, the selection of a probability distribution to represent an input factor in the exposure models should be based upon any gathered information about that factor: theoretical arguments and/or expert opinions. A probability distribution can be ascertained for such information as the following: general shape of the distribution, minimum, maximum, mode, mean, median, midrange, and other percentiles. Available data on the probability distributions for each of the exposure factors discussed in this handbook have been presented in previous sections. When distribution data are not available, distributions can be assigned using professional judgement.

Although the exact shape of many of the distributions is not known, the estimated distributions approximate the current state of knowledge about these variables much better than a single point estimate. From the data presented in EFH, it may be seen that for each variable, a range of values exists. In many cases, additional information such as central tendency values (e.g., mean, median) and/or percentiles is provided. Selection of a single point estimate from such data is a significant loss of information. In effect, a point estimate is a distribution in which a single value has a 100 percent chance of occurring and all other values have no chance of occurring. The data presented in EFH is capable of providing much more information than a single point estimate, particularly for the purpose of risk assessment.

A further consideration is that exposure parameters may not be independent. For example, there is typically a positive correlation between inhalation rate and body weight. A range of values

may be identified in the literature for this correlation. These correlations range from moderate to moderately high.

C 7 3 Qualitative Uncertainty Analysis

A qualitative uncertainty analysis can be used to estimate the impact of aspects of a risk assessment.

The initial characterization that defines the risk assessment for a site involves many professional judgments and assumptions. Definition of the physical setting, population characteristics, and selection of the chemicals included in the risk assessment are examples of areas for which a quantitative estimate of uncertainty cannot be achieved because of the inherent reliance on professional judgement.

Assumptions and supporting rationale regarding these types of parameters, along with the potential impact on the uncertainty (i.e., overestimation or underestimation of uncertainty) are described qualitatively above as part of the qualitative exposure assessment uncertainty analysis. A qualitative uncertainty analysis is presented in Table 1.

Table C 7 1
Selected Qualitative Uncertainty Factors

Uncertainty Factor	Effect of Uncertainty	Comment
Fate and Transport Estimation		
Assumed house volume and ventilation rate	May slightly overestimate or underestimate risk	The indoor concentration of soil gas penetrating the foundation depends on indoor ventilation
Soil gas source term assumptions	May overestimate or underestimate risk	The heterogeneous sources were assumed to be homogeneous
Natural infiltration rate	May overestimate risk	A conservative value was used for this parameter
Moisture content	May overestimate or underestimate risk	This varies seasonally in the upper vadose zone and may be subject to measurement error
Water table fluctuations	May slightly overestimate or underestimate risk	The average value used is expected to be representative of the depth over the 25 year exposure period
Modeling of VOCs from soil gas through the foundation	May over estimate or underestimate risk	There may be DNAPLs in the vadose zone however conservative assumptions were used in the modeling from the saturated zone
Variability in annual meteorological data	May slightly overestimate or underestimate risk	Although a rigorous statistical analysis on annual variability was not conducted the annual variability is less than approximately 1% in each category resulting in less than approximately 5% from year to year
Exposure scenario assumptions	May overestimate risk	The likelihood of future onsite residential development is small If future residential use of this site does not occur then the risk estimates calculated for future onsite residents are likely to overestimate the true risk associated with future use of this site
Exposure parameter assumptions	May overestimate risk	Assumptions regarding media intake population characteristics and exposure patterns may not characterize actual exposures
Exposure Estimation		
Exposure duration	May overestimate or underestimate risk	The assumption that an individual will work or reside at the site for 25 or 30 years is conservative Short term exposures involve comparison to sub-chronic toxicity values which are generally less restrictive than chronic values

Non chemical specific constants (not dependent on chemical properties)	May overestimate risk	Conservative or upper bound values were used for all parameters incorporated into intake calculations
Toxicological data		
Exclusion of some hypothetical pathways from the exposure scenarios	May underestimate risk	Exposure pathways were rigorously evaluated for each scenario and eliminated only if it was determined that they were either incomplete or negligible compared to other evaluated pathways
Permeability coefficients	May slightly overestimate or underestimate risk	EPA permeability coefficients were algorithmically predicted and have an uncertainty of approximately one order of magnitude
Use of cancer slope factors	May overestimate risk	Potencies are upper 95th percentile confidence limits. Considered unlikely to underestimate true risk
Critical toxicity values derived primarily from animal studies	May overestimate or underestimate risk	Extrapolation from animal to humans may induce error due to differences in absorption pharmacokinetics target organs enzymes and population variability
Critical toxicity values derived primarily from high doses most exposures are at low doses	May overestimate or underestimate risk	Assumes linear at low doses. Tend to have conservative exposure assumptions
Critical toxicity values and classification of carcinogens	May overestimate or underestimate risk	Not all values represent the same degree of certainty. All are subject to change as new evidence becomes available
Lack of inhalation slope factors	May underestimate risk	Carcinogenic COCs without inhalation slope factors may or may not be carcinogenic through the inhalation pathway
Use of oral slope factors to evaluate dermal absorption	May overestimate or underestimate risk	Assumes that introduction to the blood stream through the skin acts similarly to absorption through the gut
Addition of risks across weight of-evidence classifications	May overestimate risk	Addition of risks across weight-of-evidence classifications is extremely health conservative and potentially inappropriate
Lack of RfDs or RfCs	May underestimate risk	Inhalation RfDs or RfCs are not available from IRIS for some chemicals
Effect of absorption	May overestimate or underestimate risk	The assumption that absorption is equivalent across species is implicit in the derivation of the critical toxicity values. Absorption may actually vary with chemical
Lack dermal absorption or direct action toxicity values	May slightly underestimate risk	The unavailability of consensus absorption values does not facilitate comparison of absorbed dose to toxicity constants based on administered dose

C 8 0 SUMMARY

These residual risk calculations discussed in this risk assessment were intended to develop a quantitative assessment of the risk associated with appropriate receptors and scenarios after specific remedial action alternatives have been implemented. Based on information from the PHE, the most conservative contamination scenarios, receptors, and pathways were evaluated. Concentrations of contaminants were modeled using groundwater modeling techniques and then receptor intakes were calculated. The intakes were combined with toxicological data in risk and HQ equations to calculate potential probabilities for carcinogenic risk and noncarcinogenic HQs. The carcinogenic risks and HQs were then summed by scenario to yield total potential carcinogenic and noncarcinogenic effects.

The maximum calculated carcinogenic risk is for the no action scenario. The total risk to the future onsite resident with groundwater is 1.17×10^{-5} .

The HIs calculated for the scenarios and receptors were not significant (i.e., did not approach unity). The maximum HI is 2.59×10^{-1} for a future onsite child resident and the no action scenario.

C 9 0 REFERENCES

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General Comments

Comment 1

DOE has incorrectly concluded that State Groundwater Standards are not applicable to Rocky Flats. This fundamental mistake will mean that much of this document must be rewritten in order to adequately assess compliance with this ARAR. DOE has not presented full rationale with supporting evidence that would convince EPA that these standards are not applicable.

Response

DOE has carefully reviewed the State's groundwater ARARs position and the regulations concerning the State's Basic Standards for Ground Water (5 CCR 1002.8.3.11.5). DOE has determined that the State's basic standards are potential ARARs for all contaminants except radionuclides. The CMS/FS will be revised to reflect this potential ARAR at OU 1.

Resolution

As discussed in meetings held on December 8 and December 14, 1994, between DOE, EPA and CDPHE, the resolution to this comment is as stated in the response above.

Comment 2

In light of the above comment, it is obvious that DOE's preferred alternative of institutions controls will not achieve compliance with State Groundwater Standards. Therefore, one of the other alternatives that will remediate groundwater must be chosen as a preferred alternative. Since the french drain and treatment plant are already in place, it seems that there is much advantage to utilizing both of these components and optimizing this system through added enhancements in order to reduce the remediation time frame. As such, it may be necessary to consider other modifications to the alternatives already presented, such as the use of surfactants, horizontal wells, etc. It is also necessary to more thoroughly and accurately evaluate the effectiveness and cost of the french drain and treatment plant, factoring in the discontinued collection of 881 footing drain water.

Response

The selection of a preferred remedy at OU 1 should be based on the results of the detailed analysis of alternatives. This approach to a preferred remedy selection is consistent with both RCRA and CERCLA and subsequent guidance under each. Assuming that a remedial action is warranted prior to examining the revised results of the detailed analysis of alternatives is both premature and potentially inconsistent with both RCRA and CERCLA guidance. DOE has followed the approach outlined in the preamble to the NCP rules concerning program goals, program management principles, and expectations (55 FR

8702 8706) Further it is not obvious that the preferred alternative recommended in the OU 1 draft final CMS/FS report would not achieve compliance with State Groundwater Standards. Until a specific point of compliance is agreed upon, the EPA's assumption that a remedial action is necessary to achieve compliance under the State Groundwater Standards (which are different from the chemical specific ARARs presented in the CMS/FS) is invalid. DOE has suggested demonstrating compliance with certain performance monitoring points prior to selection of a remedy while compliance at several locations is evaluated by the agencies and the public.

Resolution

As discussed in the meeting held on December 14, 1994, between DOE, EPA and CDPHE, the results of the revised CMS/FS report will be reviewed prior to selecting a preferred remedy for OU 1. The results of the revised detailed analysis of alternatives will be presented to both agencies and input will be solicited at that time for selecting an appropriate remedial action for preparation of the proposed plan for OU 1.

Comment 3

The FS states that the preferred alternative for OU1 is institutional control without the french drain but with groundwater monitorings. Under this strategy, chlorinated solvents in the subsurface will continue to contaminate groundwater until sources diminish through natural processes. However, due to some uncertainty regarding the location and nature of the sources, it is difficult to determine with confidence how long institutional controls and groundwater monitoring will be required. Modeling results presented in the FS indicate that concentrations at Woman Creek will continue to increase until the year 2369 or for 375 years into the future. To ensure that Woman Creek is protected, it follows that groundwater monitoring will be required as long as concentrations increase, but only 30 years of monitoring is accounted for in the cost estimate for the preferred alternative.

Response

Due to the impact of present worth analysis on cost estimates of monitoring periods extending beyond 30 years, EPA guidance recommends that costs occurring beyond thirty years be neglected in feasibility study cost analyses. Specifically, the *Remedial Action Costing Procedures Manual* (EPA 1987) states on page 3-21 "Remedial action alternatives requiring perpetual care should not be costed beyond thirty years for the purpose of feasibility analysis. The present worth costs beyond this period become negligible and have little impact on the total present worth of an alternative." Also, the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988) states on page 6-13 "In general, the period of performance for costing purposes should not exceed 30 years for the purpose of detailed analysis. In addition, 30 year monitoring periods are required under RCRA for closure actions that may impact groundwater (6 CCR 1007.3-264.117). The costing of monitoring periods for thirty years does not limit the actual monitoring period, which would be extended if continued monitoring is required."

Resolution

As discussed in the meeting held on December 14, 1994, between DOE, EPA and CDPHE, the monitoring period described in the CMS/FS report will remain at 30 years as prescribed by guidance, except for remediation alternatives which may limit the amount of monitoring required.

Comment 4

The source removal remedial alternatives offer the possibility of removing source areas and potentially reducing the post closure monitoring period and the potential for future corrective action. Therefore the time required to reach remedial action objectives (RAOs) is one of the major difference among the three general types of alternatives evaluated (monitoring, containment, and source removal followed by residual contaminant containment and monitoring). The FS must evaluate the time element in more detail before a remedial alternative is recommended. The report must also provide more discussion about the uncertainty of the source extent and how this uncertainty affects the effectiveness of the source removal technologies. These discussions must also consider the degree of confidence gained after the proposed soil gas study is conducted. In addition, the FS must estimate the time it will take to reach a point when monitoring is no longer required for each alternative and incorporate these results into the comparative analysis. The FS must also consider the uncertainty associated with the models when evaluating the effectiveness of the various strategies. Finally, the FS should incorporate a sensitivity analysis into the model results to further evaluate the impact of subsurface contaminant uncertainty.

Response

Where possible, the elements of this comment will be included in the revised CMS/FS report. In particular, more text will be added to the document discussing the uncertainties involved with each remedial action and with the source areas in general. However, it is because of the large uncertainty associated with the source areas at OU 1 that it was not deemed appropriate to specify the monitoring periods required for each alternative. Until data are available concerning the actual performance of a remedial action at OU 1, it is impossible to accurately predict the monitoring period required for any alternative other than through standard guidance (i.e., 30 years). In addition, it is believed that these time periods will not affect the selection of a preferred remedy and therefore are not critical to the detailed analysis of alternatives.

Uncertainties associated with the groundwater model will be discussed further in the revised CMS/FS. A sensitivity analysis was suggested by DOE previously but could not be accomplished in the schedule provided. Both EPA and CDPHE acknowledged this fact and agreed that it would not be presented in the draft final CMS/FS. A sensitivity analysis will be initiated for the OU 1 CMS/FS and will be incorporated based on schedule constraints.

Resolution

As discussed in meetings held on December 8 and December 14, 1994, between DOE, EPA, and CDPHE, the resolution to this comment is as stated in the response above.

Comment 5

Given the proximity of OU1 to Woman Creek, one of the primary functions of any remediation that occurs at OU1 should be to protect Woman Creek and the associated ecological receptors. Therefore, protecting ecological receptors associated with Woman Creek must be an RAO for OU1.

Response

This issue will be discussed further through a special work group designated by DOE and the regulatory

agencies to resolve specific comments. However, this exposure route was not included in the RFI/RI report or the BRA and it is unclear why the EPA is raising the issue at this time.

Resolution

As discussed in meetings held on December 8 and December 14, 1994, between DOE, EPA and CDPHE, this comment will be resolved by including additional detail in the short term effectiveness evaluation of each alternative concerning impacts to Woman Creek and other environmental receptors. In addition, an RAO will be added to include protection of ecological receptors in Woman Creek.

Comment 6

It is uncertain whether Woman Creek and the associated ecological receptors will be protected under the proposed remedial alternative. Throughout the FS, the text states that maximum contaminant levels (MCLs) need to be met only at Woman Creek to be protective. It is not clear whether MCLs will protect ecological receptors associated with Woman Creek. The FS must be revised to illustrate how Woman Creek ecological receptors will be protected from OU1 contamination.

Response

See response to General Comment #5.

Resolution

See resolution to General Comment #5.

Comment 7

More detailed discussion about the proposed monitoring plan must be added to the FS, particularly since monitoring is one of the primary features of the preferred alternative and is common to all alternatives. The alternatives that would suspend french drain operations but leave it in place (Alternatives 0 and 1) imply that monitoring will continue and that the french drain will be reactivated only if monitoring results exceed predicted values. The only locations for which predicted values are given in Appendix B are both down gradient of the french drain. The text does not specify which monitoring wells correspond to these locations. Regardless, by the time concentrations begin to exceed predicted values down gradient of the french drain, it may be too late for the french drain to be effective. If a contamination front is detected below the french drain, it is probable that the contaminants have already spread throughout the length of the french drain. Monitoring wells that will be used to trigger remedial decisions should be located above the portion of the french drain that intersects the expected contaminant flow path. Currently, the closest well reported to have 9,500 micrograms per liter ($\mu\text{g/L}$) of trichloroethene (TCE), 2,600 $\mu\text{g/L}$ of carbon tetrachloride, and 590 $\mu\text{g/L}$ of tetrachloroethane (PCE) from a sample collected in late 1992. On the basis of these results, french drain operation should not be discontinued under any of the alternatives. If future wells are planned for the area above the french drain, investigative methods should be used that will optimize the well location with respect to bedrock topography and the contaminant plume.

Response

The location of monitoring wells is typically not a component of the CMS/FS as it does not affect alternative development or the detailed analysis of alternatives. This information is usually included in the PRAP/PP CAD/ROD or in a post closure monitoring plan. More information regarding the monitoring plan will be incorporated into the CMS/FS report at the agency's request although DOE disagrees that the information is relevant to the remedy selection process. Note that both regulatory agencies will have input to the monitoring plan through any of the documents mentioned above.

Resolution

As discussed in meetings held on December 8 and December 14, 1994 between DOE, EPA and CDPHE the resolution to this comment is as stated in the response above.

Comment 8

There is no mention in this document of the buried gas transmission line that crosses OU1 in an east west direction between 119 1 and the French Drain. The existence of this feature could certainly impact some of the alternatives discussed in this document. Additionally, since this line lies in the path of the migrating contaminated groundwater, an evaluation of how it might be affecting migration is needed.

Response

It is unclear how this comment could impact the remedial action alternatives presented in the CMS/FS report. The line is a utility feature which will undoubtedly be reviewed during detailed design. The purpose of the CMS/FS report is to evaluate conceptual approaches to remediation of OU 1. Details such as the transmission line do not impact the analysis, especially in the case where the line is not in the immediate vicinity of the treatment zone as is the case here. In addition, evaluation of the transmission line as a potential route for contaminant migration is not within the scope or purpose of the CMS/FS report. This issue should have been raised during the preparation of the RFI/RI report if EPA felt that it warranted significant attention.

Resolution

As discussed in meetings held on December 8 and December 14, 1994 between DOE, EPA and CDPHE this comment will be resolved by including a reference to the gas transmission line wherever alternatives are presented that could potentially be impacted by the presence of the line.

Comment 9

This report fails to make use of all available and pertinent data, and this is especially critical in the ground water modeling that was performed. Apparently only analytical data from 1990 through mid 1992 was used in the modeling, even though data from 1987 to the present is readily available for this purpose. Nor were the soil gas survey results from December 1993 mentioned or presented, although a much older (pre 1987) soil gas survey was cited a few times in the text. What happened to the cores and associated data that were proposed in the OU1 Treatability Study Work Plan: Soil Flushing, Biotreatment, and Radio Frequency Heating, September, 1992? That work plan was designed for the purpose of collecting site

specific data to be used in evaluating alternatives for the OU1 CMS/FS and any data that was collected must be presented in this report

Response

DOE believes it is appropriate to use the data set considered in the RFI/RI report for the groundwater model constructed for the OU 1 CMS/FS. Groundwater monitoring data for the hillside is available to the present date and will continue to be available in the future. However, the groundwater model must consider a data set that is static and cannot be updated continuously based on current monitoring programs. The data set selected for the model is the most appropriate data set to use given its use in the RFI/RI report to which results of the model are being compared. Remedy selection is based on the results of the CMS/FS report which in turn is based on the results of the RFI/RI report. However, at the request of both agencies, the groundwater model has been revised to include data through 1994. It is assumed that this data will be sufficient to satisfy this comment.

Note that the intent of the treatability study work plan was not to gather soil characterization data. Rather, the intent of the study was to gather soil samples for testing of various treatment technologies. Unfortunately, soil samples recovered contained few if any detectable concentrations of contaminants even though they were taken from the most probable contaminant regions at IHSS 119.1. Data from the tests themselves were supposed to be used for evaluating alternatives. Since the tests were not performed due to the unavailability of contaminated soils, the data are not available to include in the CMS/FS report.

The CMS/FS report will be revised to reference both soil gas surveys. The data was used indirectly in the CMS/FS during conceptualization of remedial action alternatives. The text will be revised to include this information.

Resolution

As discussed in meetings held on December 8 and December 14, 1994, between DOE, EPA, and CDPHE, the resolution to this comment is as stated in the response above.

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General Comments

Comment 1

General Lack of Response to Division Comments The Division finds that the DOE has in general failed to adequately respond to or resolve the vast majority of our comments and concerns in this draft CMS/FS report. These concerns were discussed with DOE staff in several meetings and are documented in the Division's comments to TM 10 and TM 11. The DOE's failure to resolve these comments has resulted in the submittal of an incomplete and inadequate draft CMS/FS.

Response

DOE has made every effort to adequately respond to comments received from both EPA and CDPHE. Many of the concerns listed in the State's comments on the OU 1 CMS/FS have not been raised during the various working meetings held between DOE, EPA, and the State since January of this year. Issues such as classification of IHSS 130 as a mixed waste landfill significantly impact the content of the OU 1 CMS/FS and should have been discussed during the identification of preliminary remediation goals and remedial action alternatives. Additionally, technical input from both agencies received during working meetings has not been representative of written comments received after review of both TMs and the CMS/FS report. For example, the State has commented heavily on the conceptual approach and parameters used to develop the OU 1 groundwater model. This information was presented to both agencies through several meetings beginning in June of this year and continuing through July. Both agencies were involved in reviewing the model as it was developed and at no time did either agency indicate a concern over the conceptual approach applied. DOE is disappointed that the State has criticized DOE's approach to the consultative process while continuing to limit the value of such meetings. These disparities have hindered proper resolution of outstanding issues, issues which often times are not discussed early in the process due to the State's consistent submittal of comments on OU 1 documents much later than EPA comments.

Resolution

During the December 8 meeting between DOE, EPA, and CDPHE it was decided that regular meetings will be held to resolve outstanding issues on the OU 1 CMS/FS report. These meetings will be instrumental in achieving a common forum through which all parties can come to agreement on specific items. Resolution will be documented herein and incorporated into the revised CMS/FS report.

Comment 2

Role of the State and RCRA Correction Action in Remedy Selection -- This Draft CMS/FS is entirely focused on CERCLA and the CERCLA process. No attempt has been made to meet the State's RCRA/CHWA requirements. Under the IAG, the State will make a Corrective Action Decision under RCRA/CHWA and the EPA will make a Remedial Action Decision under CERCLA. The CMS/FS must be adequate to support both Agencies' decisions. The IAG specifically requires that Feasibility Studies / Corrective Measures Studies comply with the requirements of CERCLA, RCRA, CHWA, and pertinent guidance and policy [paragraph 152]. The Division has stated on many occasions, both formally and informally, that the CERCLA process is only a template and some modifications to the process will be necessary to meet RCRA/CHWA CMS requirements. The DOE has repeatedly ignored these Division concerns.

In this draft CMS/FS report, the DOE's position continues to be that consistency with CERCLA RI/FS guidance takes precedence over meeting RCRA/CHWA CMS needs and requirements. The DOE's failure to address this issue has resulted in the submittal of a deficient CMS/FS document that does not meet the State's needs in making a corrective action decision for all IHSSs in OU 1. The DOE must fully recognize and meet all RCRA/CHWA requirements in the Final CMS/FS and, where necessary, deviate from CERCLA FS guidance to meet such requirements. Consistency with CERCLA guidance is not sufficient justification for ignoring the Division's concerns and comments.

Response

DOE disagrees with the State's comment that the draft final CMS/FS report is focused solely on CERCLA and the CERCLA process. Comments further state that no attempt has been made to meet the State's RCRA/CHWA requirements. CERCLA evaluation criteria duplicate RCRA evaluation criteria and include additional criteria which address community and state acceptance. The State has acknowledged that Section 4.0 of the report was not reviewed. This section represents the core of the CMS/FS and contains a detailed evaluation of both RCRA and CERCLA criteria. DOE requests that the State specify what requirements are not being met under RCRA/CHWA, since the detailed analysis of alternatives includes discussions on RCRA standards, evaluation criteria, and source control measures. Additional information regarding specific deficiencies is requested prior to responding to this comment. For information purposes, the following table lists the evaluation criteria considered under both CERCLA and RCRA guidance.

National Contingency Plan, Evaluation Criteria 40 CFR 300.430 (e) (9) (iii)	RCRA Corrective Action Plan Guidance Evaluation Criteria OSWER Directive 9902.3-2A (May 1994)
Overall protection of human health and the environment	Protect human health and the environment
	Control the sources of releases ¹
Compliance with ARARs	Comply with any applicable standards for management of wastes
	Attain media cleanup standards set by the implementing agency
Long term effectiveness and permanence	Long term reliability and effectiveness
Reduction of toxicity, mobility, or volume through treatment	Reduction in the toxicity, mobility, or volume of wastes
Short term effectiveness	Short term effectiveness
Implementability	Implementability
Cost	Cost
State acceptance	
Community acceptance	

This criterion is addressed under the National Contingency Plan threshold criteria for Overall Protection of Human Health and the Environment. This criterion is also directly related to the Long Term Effectiveness and Permanence criteria.

Resolution

During the December 8 meeting it was made clear that the State felt that the OU 1 CMS/FS report did not adequately address the RCRA CAP criteria in the detailed analysis of alternatives (DAA). The State suggested a separate working session to review the DAA and to provide input into the presentation of Section 4.0 of the CMS/FS. DOE agrees that this approach will resolve this comment and agrees to provide more information in the report on the RCRA CAP process and how it is integrated with the CERCLA process. Summary tables in Section 4.0 of the report will be revised to include specific CAP criteria where the criteria differ from those evaluated under CERCLA. For example, source control measures will be specifically discussed in the DAA to address this CAP criterion.

Comment 3

DOE Inappropriate Proposal for a CAMU The DOE has proposed as part of all remedial alternatives for OU 1 that the Division designate the 881 Hillside at RFETS as a corrective action management unit (CAMU). The DOE's sole intention in proposing this designation appears to be avoiding the active clean up of the hillside. The Division is bewildered by the DOE's apparent lack of understanding of the intent and substance of the CAMU regulations. The intent of CAMU is to facilitate an effective and efficient remedy, not to avoid the need for active corrective action. The Division finds the application of CAMU proposed by the DOE in this document to be inconsistent with the intent of the CAMU regulations and both the substantive and administrative requirements of CAMU.

The Division is extremely disappointed that we were not consulted on this proposal or notified of the DOE's intention to apply CAMU at OU 1 prior to the submittal of this CMS/FS report. Based on our evaluation of all information available under OU 1, the Division finds no basis for designating OU 1 a CAMU. If the DOE can provide sufficient information supporting the appropriateness of a CAMU at OU 1, this information must be discussed and a CAMU designation agreed to by the Agencies prior to its inclusion in the Final CMS/FS.

Response

DOE has proposed use of the Subpart S hazardous waste requirements as a possible means of achieving an effective and efficient remedy for OU 1. The information on the Corrective Action Management Unit (CAMU) rule that DOE has access to is the Commission's proceedings on adopting the rule and the rule itself (6 CCR 1007.3.264.552). The CAMU approach to OU 1 was proposed in this draft final CMS/FS for review and discussion with the State, as is required under the CAMU rule. If the State does not agree that the CMS/FS report is the proper forum for discussing the CAMU concept at OU 1, then DOE requests that the State suggest an appropriate forum for this discussion within the confines of the IAG.

Resolution

During the meetings held on December 8 and December 14, 1994, between DOE, EPA, and CDPHE, it was agreed that the CAMU language will be removed from the CMS/FS report. CDPHE agreed that an IHSS by IHSS evaluation is not required for alternative development as long as each source area and IHSS is identified in the OU 1 CMS/FS and dispositioned in terms of remedial actions. The CAMU concept was proposed to retain an OU-wide approach to alternative analysis at OU 1. Based on the State's revised position on the IHSS by IHSS evaluation issue, the CAMU language will be removed.

Comment 4

Information Necessary to Support a Corrective Action Decision -- This comment was originally made to TM 11 and has not been resolved to the Division's satisfaction in the Draft CMS/FS. The draft CMS/FS does not contain sufficient information to support a CAD for all of the IHSSs in OU 1. The Division will not consider the Final CMS/FS to be complete until all IHSSs and/or source areas in OU 1 are sufficiently addressed. This draft CMS/FS only addresses contamination at IHSS 119.1 at a minimum; the group of IHSSs south of Building 881, IHSS 130, and IHSS 119.2 must also be evaluated.

This concern was raised in the Division's comments to the draft TM 11 and clarified in a meeting with DOE and EG&G staff. The DOE formally responded to this concern on September 30, 1994, almost a month after releasing the draft CMS/FS. The Division finds the DOE response to this comment inappropriate, inaccurate, and inconsistent with both the IAG and the risk screening approach that all parties agreed to.

The evaluation of each IHSS is consistent with the CERCLA process and has been recognized by the EPA as necessary and appropriate for all OUs at RFETS. Regardless of CERCLA guidance, the Division requires the CMS/FS contain sufficient information to fully support a corrective action decision by the Division under RCRA/CHWA for each IHSS and/or source area in OU 1.

The DOE disagreement with the Division's application of the risk screening approach is concerning. This screening methodology was agreed to by all parties, including the DOE.

The development of remedial action alternatives must start at the IHSS and/or source level. Corrective measures must be selected for each IHSS and/or source area that are fully protective and meet all appropriate RAOs and PRGs. The number and range of alternatives evaluated for each IHSS and/or source area may be limited by the scope and complexity of contamination and availability of treatment options. Alternatives selected for each IHSS should then be combined to form a range of remedial action alternatives for the operable unit. When appropriate, IHSSs with similar effective alternatives can be combined to achieve economies of scale. Alternatives developed at the operable unit level must provide the range of alternatives prescribed in EPA guidance.

The Division recognizes that it may not be efficient to address all contamination strictly through IHSSs; in some instances it may be more efficient to address an area of contamination as a source area independent of the IHSSs. This does not mean that each IHSS does not need to be addressed.

The DOE statement in response to this comment under TM 11 that the groundwater contamination at the eastern edge of the operable unit has not been definitively tied to any one IHSS is correct but totally misleading. As reported in the OU 1 RFI/RI Report, this contamination was in fact attributed by the DOE to multiple IHSSs, although not definitively. To definitively tie the contamination on the eastern edge of OU 1 to IHSS 119.2 and/or the 903 Pad would require additional, largely unnecessary, characterization field work. Regardless of the source of contamination near IHSS 119.2, it must be addressed in the OU 1 CMS/FS.

Response

The meetings referenced in this comment were held during the preparation of the OU 1 CMS/FS report. Both regulatory agencies have repeatedly denied DOE's informal requests to extend the schedule for preparation of the CMS/FS report. Many of the comments received on the OU 1 CMS/FS are based on

unresolved issues from the OU 1 RFI/RI report. The State must recognize that many of these issues impact the CMS/FS directly and therefore impact its schedule. Because both agencies have repeatedly insisted that the CMS/FS report be produced prior to resolution of these issues, agreements made between the agencies and DOE may not be represented in the draft final CMS/FS.

In addition, as stated in the response to comments received on TM 11, DOE does not agree that individual IHSSs should be examined for remedial action alternatives. The IAG states that the CERCLA RI/FS guidance should be used as the template for conducting OU CMS/FSs. The IAG also establishes the OU concept and recognizes the need for evaluating remedial actions at the OU level. The OU concept is particularly suited to the circumstances of OU 1, where unspecified sources of groundwater contamination have resulted in OU wide contamination at various levels. The OU 1 RFI/RI document also does not support an IHSS by IHSS evaluation. If the State feels that IHSSs should be evaluated individually for overall protection to human health and the environment, then the State should initiate these evaluations through the RFI/RI process and not the CMS/FS process. The BRA results must at some point be used by the State to determine if further action is warranted at a site, or in this case, at an IHSS. It is inappropriate for the State to request that the CMS/FS be used as a vehicle to identify no action decisions prior to conducting a detailed analysis.

DOE requests that the State provide additional guidance on the value of evaluating each IHSS and source area independently in the OU 1 CMS/FS report. As the last paragraph of this comment suggests, the contamination near IHSS 119.1 must be addressed regardless of its source. DOE does not believe that the groundwater medium beneath OU 1, which represents the highest potential risk to viable receptors, can be evaluated on the basis of individual IHSSs. DOE has proposed alternatives that remediate both the most contaminated areas of OU 1 groundwater, as well as the OU as a whole. These alternatives adequately represent potential remedial action strategies at this OU. To address this comment, the revised CMS/FS will contain additional information regarding each IHSS's status in terms of each alternative.

Resolution

During the December 8 meeting, the State voiced the concern that the public may not be able to follow the decision process if individual IHSSs are not specifically discussed in the OU 1 CMS/FS report. DOE suggested that IHSSs be discussed early in the report to identify specific source areas. These source areas will then be addressed separately and evaluated for remedial action. The discussion on IHSSs and how they are addressed by the source area approach will be included in future documents (such as the Proposed Remedial Action Plan/Proposed Plan) as well. The State concluded that individual alternative analyses are not required for each IHSS as long as each IHSS is included in the initial discussion of source areas. Also see resolution to General Comment #4.

Comment 5

RCRA/CHWA Criteria for the Evaluation of Final Corrective Measure Alternatives – The Division will use the RCRA corrective action evaluation criteria presented in the latest version of the RCRA Corrective Action Plan (OSWER Directive 9902 3 2A May 1994) a guidance document produced by EPA for implementation of RCRA corrective action as guidance in evaluating remedial action alternatives. These standards reflect the major technical components of remedies including cleanup of releases, source control and management of wastes that are generated by remedial activities.

The specific standards as set out in the RCRA CAP guidance include 1) protect human health and the environment 2) Attain media cleanup standards set by the implementing agency 3) Control the source of release so as to reduce or eliminate to the extent practicable further releases that may pose a threat to human health and the environment 4) Comply with any applicable standards for management of wastes 5) Other factors. Other factors include five general factors that will be considered as appropriate by the Division in selecting a remedy that meets the four standards above. The five general factors include a Long term reliability and effectiveness b Reduction in the toxicity, mobility or volume of waste c Short term effectiveness d implementability and e Cost.

RCRA/CHWA corrective action remedies must meet the above listed standards. Therefore the Final CMS/FS must provide detailed documentation of how the potential remedy will comply with each of the Five RCRA CAP standards.

Response

DOE believes that the five criteria of EPA's RCRA Corrective Action Plan (OSWER Directive 9902 3 2A pp 63 67) and the nine criteria of the National Contingency Plan (NCP) in 40 CFR 300.430(e)(9) are essentially identical (see Table in response to General Comment #2). It is DOE's understanding that EPA has strived over the last seven years to provide guidance that can be consistently implemented at various sites with the same contaminants under the two sets of regulations. The overall objective of the two acts is the same in situations of contaminant releases and agency selection of remedies. Specific differences would seem to point to additional criteria in the NCP regulations such as community acceptance. It is emphasized that the RCRA Corrective Action Plan is a guidance as is the CERCLA RI/FS guidance.

The State asserts that RCRA/CHWA corrective action remedies must meet the listed standards and suggests that the CMS/FS provide detailed documentation of how the potential remedy will comply with each of the standards. It is DOE's position that in fact the referenced standards are not standards but evaluation criteria. These criteria are evaluated in the detailed analysis of alternatives presented in Section 4.0 of the CMS/FS report. Until the State has reviewed this section of the document, it is inappropriate to assume that the RCRA CAP evaluation criteria are not included.

Resolution See Resolution to General Comment #2

Comment 6

Effectiveness of Remedial Action/Corrective Action to Protect the Environment – This comment was originally made to TM 11 and has not been resolved to the Division's satisfaction in the Draft CMS/FS

The general assumption that remedial actions at OU 1 that are protective of human health will adequately protect ecological receptors and environmental resources at OU 1 is not appropriate in the CMS/FS report. The effectiveness of each alternative to protect the environment must be evaluated. The DOE response to this comment under TM 11 that it is not necessary to consider environmental protectiveness in the OU 1 CMS/FS because the OU 1 BRA EE did not identify any significant hazards to ecological receptors is not an acceptable response.

The BRA EE finds that many of the contaminants evaluated in the BRA EE are toxic to ecological receptors at concentrations found at OU 1 but that because of the limited extent of contamination no adverse ecological impacts occur. The assumption that contamination is limited and no adverse ecological impacts will occur is not valid under all of the OU 1 CMS/FS remedial alternatives specifically those alternatives which allow contamination to continue to migrate uncontrolled could invalidate this assumption. The effectiveness of all remedial alternatives to protect the environment must be fully addressed in the Final CMS/FS.

Response

The assumption that remedial actions at OU 1 that are protective of human health will be protective of ecological receptors is based on the results of the OU 1 RFI/RI report. The results of the which indicate that there is no current or future significant risk to these receptors. The effectiveness of each alternative to protect the environment is evaluated in the detailed analysis of alternatives (Section 4.0). This section was not reviewed by the State and therefore the comment that this evaluation was not conducted may be premature.

The State concludes that the assumption that contamination is limited and no adverse ecological impacts will occur is not valid under all of the OU 1 CMS/FS remedial alternatives due to the potential for contaminant migration. This assumption is based on the RFI/RI surface soil evaluation and is not related to groundwater contamination which is the focus of the CMS/FS report. The groundwater medium was not identified as a potential source of future risk to ecological receptors and therefore the assumption is valid unless the State has identified future risks to ecological receptors from groundwater contaminants that are not identified in the OU 1 RFI/RI report.

Resolution

During the meetings held on December 8 and December 14, 1994 between DOE, EPA and CDPHE it was agreed that the resolution to this comment will be present a more thorough analysis of short term impacts to the environment under the Detailed Analysis criterion of Short Term Effectiveness.

Comment 7

Incomplete and Inaccurate Identification of ARARs The Division has commented on several occasions regarding specific deficiencies in the identification of ARARs for OU 1. The Division has expressed major concerns with the DOE's identification and determination of ARARs under TM 10. The majority of the Division's comments and concerns regarding ARARs have not been adequately addressed and remain unresolved in this draft CMS/FS. In comments to TM 11, the Division deferred ARARs comments in hope that several outstanding issues could be resolved through the ARARs Working Group. Unfortunately, the DOE has chosen to proceed at an extremely slow pace under the ARARs working group and the group has yet to entertain substantive ARARs discussions.

The Division's general comments on specific potential ARARs are presented below. Additional ARARs comments are also included in the Division's specific comments. All ARARs issues must be resolved in the Final CMS/FS before the Division will consider the document to be complete.

- a) State Groundwater Standards The DOE has failed to present any valid argument to support its claim that the State groundwater standards are not ARARs. This document states that groundwater standards are not addressed ARARs because the classifications requiring those standards have not been applied consistently throughout the State and thus fail the NCP criteria of general applicability in 40 CFR 300.400 (g) (4). This argument, much like the last two arguments against the application of State groundwater standards as ARARs, is simply incorrect. Contrary to this argument, the phrase "general applicability" has nothing to do with whether or not standards have been applied consistently. The preamble to the NCP explains that "of general applicability" means that potential State ARARs must be applicable to all remedial situations described in the requirement, not just CERCLA sites. Consistent with the preamble's explanation, State groundwater standards are applicable to all situations, not just CERCLA sites, and therefore are of general applicability. Moreover, no classifications exist for organics; rather, the standards for organics apply statewide regardless of classification. Therefore, the claim that the classifications requiring those standards have not been applied consistently makes no sense.
- b) RCRA/CHWA Subpart F Groundwater Protection RCRA/CHWA groundwater protection standards were identified in the Division's comments to TM 10 as potential chemical specific ARARs. They have not been included in the draft CMS/FS. These standards must be identified as potential ARARs in the Final CMS/FS.
- c) Doctrine of Sovereign Immunity The DOE, in response to Division and EPA comments on sovereign immunity, has stated that it has removed such language from the text of the CMS/FS but that questions regarding sovereign immunity may still be discussed during ARARs working group meetings. The Division and EPA positions on sovereign immunity appear to be clearly presented; however, if the DOE has any remaining questions at OU 1, they must be raised under this CMS/FS Report.
- d) Surface Water Standards State surface water standards were identified in the Division's comments to TM 10 as potential chemical specific ARARs. They have not been included in the draft CMS/FS. These standards must be identified as potential ARARs in the Final CMS/FS.

- e) Closure of French Drain The requirements for the final closure of the french drain must be identified as ARARs and included in the detailed analysis of alternatives
- f) Radioactive, Hazardous and Mixed Waste Landfill Requirements -- The Division considers IHSS 130 to be a mixed hazardous waste landfill which must be closed in accordance with all applicable landfill regulatory requirements. Therefore the DOE must identify all ARARs and TBC associated with landfills in this CMS/FS. This determination is based on the documented disposal of radioactive waste in the IHSS, the known or suspected disposal of hazardous waste debris associated with the OPWL in the IHSS, and the detection of hazardous waste constituents in groundwater monitoring wells directly downgradient of the IHSS. This landfill is located on an unstable hillside, is not capped and has no controls in place to prevent future release or exposure to hazardous constituents or radionuclides. Regardless of the current risk associated with IHSS 130, the DOE must meet all appropriate regulatory criteria for landfills. The DOE must identify all ARARs relevant to solid, radioactive, hazardous and mixed waste landfills.

Response

DOE disagrees with the statement that the identification of ARARs in the OU 1 CMS/FS is incomplete. The State may disagree with the selection of ARARs, however, the identification of ARARs in the CMS/FS and in TMs 10 and 11 was performed according to guidance and regulations (40 CFR 300.430(b)(9), (d)(3), (e)(2) and (e)(9)). During the review of TM 11, the State emphasized that action specific ARARs were being reviewed and comments would follow shortly. These comments were never received and therefore State comments were not available prior to preparation of the CMS/FS report. The following responses are applicable to other portions of this comment.

- a) DOE has carefully reviewed the State's position and the regulations concerning the State's Basic Standards for Ground Water (5 CCR 1002.8.3.11.5). DOE has determined that the State's basic standards are potential ARARs for all contaminants except radionuclides. The CMS/FS will be revised to reflect this potential ARAR at OU 1.
- b) The RCRA groundwater protection standards (6 CCR 1007.3.264 Subpart F) were briefly mentioned in the detailed analysis of alternatives in the CMS/FS. The CMS/FS will be revised to clarify that the RCRA groundwater protection standards are potential chemical specific ARARs and that the process of establishing groundwater protection standards at the point of compliance is part of the selection of a protective remedy under RCRA and CERCLA. The RCRA groundwater protection standards are maximum contaminant levels, background levels, or alternate concentration levels as approved by the Director (6 CCR 1007.3.264.94). It is noted that MCLs were used in the CMS/FS as the potential chemical specific ARARs and thus used to identify PRGs.
- c) This comment is noted. DOE believes that the proper forum for further discussion of sovereign immunity is the ARARs working group.
- d) Although the State identified the Colorado surface water quality standards as potential chemical specific ARARs earlier in the CMS/FS process, surface water has not been one of the media investigated at OU 1. The RFI/RI identifies soil and groundwater as the media of concern within the boundaries of OU 1. Information presented in the RFI/RI on the water quality of Woman Creek and the South Interceptor Ditch is from OU 5 and other locations.

- e Clarification of this comment is required in order to respond to the comment. The French drain collects ground water and to our knowledge is not a waste unit. DOE is unfamiliar with specific requirements applicable to closure of a French drain. DOE requests that the State provide specific references to support the comment.
- f The identification of IHSS 130 as a mixed waste landfill is the first comment from the State on this subject since the initial preparation of the CMS/FS report. The RFI/RI report did not identify this issue and the comment was never raised by the State. DOE requests that the State specify its requirements for determining what areas are considered mixed waste landfills at the RFETS and what regulatory basis is being used for these designations.

Resolution

This comment is being resolved through the ARARs working group. Comments a, b, and d are resolved as stated in the responses above; however, comments e and f could not be substantiated by the Division in terms of providing regulatory justification for the comments. Closure requirements or performance standards are not available for the French Drain. Likewise, the Division could not justify the position that IHSS 130 is a mixed waste landfill. The CMS/FS report will be revised as appropriate to clarify the text.

Comment 8

Point of Compliance with Preliminary Remediation Goals The DOE has incorrectly determined Woman Creek as the point of compliance for protectiveness and ARARs requirements at OU 1. State groundwater standards are applicable to all groundwater in OU 1. The point of compliance for groundwater PRGs at OU 1 is therefore anywhere that groundwater is present at OU 1. That is, they both must be met. The correct point of compliance must be incorporated into this report and utilized in the development and screening of alternatives. Once a remedy is selected, a new point of compliance for remedy effectiveness will be chosen and specifically delineated.

Response

Woman Creek has not been selected as a point of compliance in the draft final CMS/FS report. DOE's position on this issue is that the point of compliance should be discussed in working meetings with the agencies. The meetings held in July 1994 with representatives from both agencies concerned groundwater monitoring and covered the subject of point of compliance. These discussions were focused on the RCRA requirements found in 6 CCR 1003.7-264.95 and the State's groundwater regulations in 5 CCR 1002.8-311.6. The RCRA requirements specify the following:

The point of compliance is a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated unit where the waste management area is

the limit projected in the horizontal plane of the area on which waste will be placed during the active life of a regulated unit

and includes horizontal space taken up by any liner, dike, or other barrier designed to contain waste in a regulated unit, or

if the facility contains more than one regulated unit, the waste management area is described by an imaginary line circumscribing the several regulated units.

Whereas the State's requirements specify that for contamination identified and reported on or before September 30, 1992, the point of compliance for the statewide standards shall be at whichever of the following locations is closest to the contamination source:

the site boundary, or

the hydrologically downgradient limit of the area in which contamination exists when identified.

The State's comment defining the point of compliance as "anywhere that groundwater is present at OU 1" appears to be inconsistent with both sets of regulations. DOE requests clarification as to the basis for the State's assertion that the point of compliance has no relation to site boundaries and that the point of compliance should be arbitrarily set in the CMS/FS only to be revised once a remedy is selected.

Resolution

Resolution to this comment is pending separate discussions concerning point of compliance issues.

Comment 9

Selection of Preliminary Remediation Goals The DOE has selected State MCLs as PRGs for OU 1 in this draft CMS/FS. While the division considers State and Federal MCLs to be potential ARARs for OU 1, the Division does not find that State MCLs are necessarily the appropriate PRGs for all contaminants for either IHSS 119.1 or the OU. Sufficient documentation supporting how and why the DOE selected State MCLs as PRGs for OU 1 is not included in the CMS/FS Report. The rationale for selecting State MCLs over risk based PRGs or other ARARs is not included in the draft CMS/FS. PRGs should be the lower of chemical specific ARARs or risk based PRGs that exceed background and appropriate PQLs. Compliance with ARARs and protection of human health and the environment are two distinct CERCLA requirements for remedies. PRG selection must be correctly implemented and fully documented in the Final CMS/FS.

Response

PRGs were established by following the NCP (40 CFR 300.430 (e)(2)(i)) and RCRA CAP guidelines (pgs. 49 and 50). DOE does not agree that groundwater PRGs should be set at the lowest possible value available regardless of the practicality of remediating to this value. This is particularly true in the case of OU 1 where groundwater is marginally available and does not present a realistic source of usable drinking water. This comment will be addressed further under the forum of the ARARs working group. Justification for selection of State MCLs was provided during the working meetings held between DOE, EPA, and the State in January of this year and is included in TM 10. At the request of both agencies, much of the material presented in the TMs was not included in the OU 1 CMS/FS to limit duplication of material. If this approach is no longer desired by the agencies, then DOE will include the material from both TMs in the revised CMS/FS report.

Resolution

During the meeting held on December 14, 1994, between DOE, EPA, and CDPHE, it was agreed that State groundwater standards will be identified as potential chemical specific ARARs for OU 1. Groundwater PRGs will therefore be based on these standards. Risk based PRGs will not be presented in the final CMS/FS report. It is assumed that State groundwater standards are considered protective by the State and therefore risk based PRGs are not required for groundwater. This is consistent with the NCP that specifies that chemical specific ARARs are generally appropriate when available. Risk based values are typically only necessary when chemical specific ARARs are not available or are otherwise not sufficient to protect human health and the environment.

Comment 10

Development of Preliminary Remediation Goals The Division does not find that the PRGs developed in section 2.3 of this draft CMS/FS adequately address all of the RAOs presented in Section 2.2 or the additional RAOs required in the Division's specific comments. The State MCLs selected by the DOE as PRGs for groundwater fail to meet the groundwater RAO as identified in this draft CMS/FS report. No PRGs have been developed to ensure protection of groundwater from degradation by subsurface soil contamination under the subsurface soil RAO. PRGs must be developed that ensure all RAOs are obtained at OU 1. This includes the complete and accurate identification of all chemical specific ARARs.

Response

DOE requests clarification of this comment. Specifically, the comment states that State MCLs fail to meet the groundwater RAO listed in the draft final CMS/FS report, then goes on to state that no PRGs have been developed to ensure that protection of groundwater from degradation by subsurface soil contamination under the subsurface soil RAO. DOE requests clarification as to which RAOs the State is referring to in regard to the MCLs. MCLs are presented as PRGs for groundwater and are not intended to target the subsurface soil medium.

In addition, subsurface soil PRGs cannot be established unless there exists a clear source of subsurface soil contamination to groundwater. Repeated efforts to obtain samples from the IHSS 119.1 area that contain possible contaminant sources have indicated that there are no clear source areas identifiable at the IHSS, and therefore no sources for which PRGs can be established and measurably achieved. With regard to ARARs, identification of chemical specific ARARs is discussed in the responses to General Comments #7 and #9 and will be addressed through the ARARs working group. It is important to note here that not all RAOs necessarily require quantified PRGs.

Resolution

Based on the meeting held on December 8, 1994, this comment will be resolved by revising the subsurface soil RAO included in the CMS/FS report to state the following: Prevent migration of contaminants from subsurface soils to groundwater that would result in groundwater contamination in excess of groundwater ARARs for OU 1 contaminants.

Comment 11

Risk Based PRG Calculation Methodology The Division specifically raised several concerns with the calculation of risk based PRGs in comments to TM 10. The DOE has failed to adequately address many of these comments. Many of these issues remain unresolved from the Final Phase III RFI/RI Report. The Division approved the Revised Final Phase III RFI/RI Report Rocky Flats Plant 881 Hillside OU1 June 1994 contingent upon DOE's revisions on a limited number of issues. These issues cannot simply be addressed by discussing them in the Phase III RFI/RI report comment response section. The Division has not been convinced by DOE's arguments and expects compliance with our requests.

The Division's major issues included: an adequate quantitative assessment of external irradiation both OU wide and at the source; a good qualitative assessment of toxicity of PAHs and PCBs and also of those chemicals for which there are not as yet any EPA toxicity factors; calculation of intake values for all those chemicals for which there are as yet no EPA toxicity factors; an assessment of surface soil exposure to the construction worker receptor; and a more objective presentation of the risks. As of yet the Division has not seen any revisions. Therefore DOE's contention that absolutely no changes will be made in the PRG documents or methodology because similar methodologies were used in the RI/RFI document is premature. The Division is particularly concerned by the DOE's refusal to calculate external exposure to radiation by a future resident. This calculation is supported both by RAGS (Part B p 35) and by ICRP 26 and 30.

Response

The concerns listed in this comment do not apply to the OU 1 CMS/FS report. They are primarily RFI/RI issues as stated in the comment and do not affect alternative development. In addition the State has requested throughout the comment document that the OU 1 CMS/FS report not include any reference to the surface soil medium. DOE seeks clarification as to why the concerns listed in this comment are presented here in light of the State's comments regarding this medium. Although the State is particularly concerned about external exposure to radiation by a future resident DOE requests clarification of how this will affect the evaluation of remedial action alternatives for groundwater at OU 1.

Resolution

Based on the meeting held on December 8, 1994 between DOE, EPA and CDPHE, this comment is not relevant to the OU 1 CMS/FS report and is therefore noted but does not require a revision to the document.

Comment 12

Failure to Consider ALL Contaminants This comment was raised in the Division's comments to TM 10 and TM 11. It has not been fully addressed by the DOE and remains a deficiency in this draft CMS/FS report.

The Division, under its corrective action authority, will consider all hazardous constituents found at OU 1 in making a corrective action decision. Therefore, the CMS must include all contaminants and cannot be limited to only the BRA COCs. The BRA COC screen was developed to focus the BRA risk evaluation on risk drivers. This screen does not preclude non COCs from being present at levels above risk based concern or that need management and monitoring. This is evident in Table 5.2 of the draft CMS/FS where many non COCs are shown to be present at OU 1 at concentrations above risk based PRGs. As stated by the Division in previous comments, the Division requires that all contaminants identified at OU 1 be included and fully evaluated in the OU 1 CMS/FS.

Response

The table referenced in this comment is unknown. In addition, DOE requests clarification on the State's position that all contaminants identified at OU 1 be fully evaluated. It is unclear in this comment how a contaminant is evaluated. The focus of the CMS/FS report is to evaluate remedial action alternatives using specific COCs as indicators to determine the effectiveness of each alternative. The CMS/FS report will be revised to specify that the complete list of contaminants are potential COCs, although the alternative evaluation process will remain unchanged.

The revised groundwater model will evaluate all of the organic contaminants identified in the OU 1 BRA. In addition, TCE will be modeled since it appears in concentrations similar to other identified BRA COCs. Other contaminants, which appear at much lower concentrations in OU 1, will be qualitatively evaluated in the revised CMS/FS report. This approach should meet the intent of this comment while preserving the integrity of the existing groundwater model.

Resolution

This comment will be addressed by the revised groundwater model, which now includes all of the BRA organic COCs as well as TCE. Other contaminants will be evaluated qualitatively but occur at much lower concentrations throughout the site and are adequately represented by the modeled COCs.

Comment 13

Subsurface Soils Preliminary Remediation Goals The DOE has repeatedly failed to respond to the Division's concerns that subsurface soil contamination is not being adequately addressed in the CMS/FS. The DOE continues to claim that subsurface soils were found not to present unacceptable risk in the BRA and thus do not require consideration. This is not correct; subsurface soils were indirectly evaluated in the BRA through groundwater pathways, many of which were found to present elevated risks.

Regardless of the BRA, hazardous constituents are present in the subsurface soils within OU 1 and must be evaluated in the RCRA/CHWA Corrective Measures Study and subsequent Corrective Action Decision. Therefore, subsurface soils must be considered along with groundwater in developing RAOs and PRGs. RAOs and PRGs for subsurface soils must be based on risk protection of groundwater and ARARs.

Response

DOE requests clarification from the State as to how subsurface soil PRGs can be developed based on risk protection of groundwater and ARARs when no direct risks have been identified in the BRA and chemical specific ARARs currently do not exist for this medium. The State has repeatedly suggested that PRGs be developed for subsurface soils without providing guidance as to what is being requested.

Additionally, given the wide variability in partitioning values found at OU 1, PRGs cannot be reliably calculated for subsurface soils based on these values. DOE therefore requests that the State clarify whether it is asking for PRGs based on ingestion of subsurface soil or on contaminant transport to groundwater. If the latter is the primary concern, then this issue should have been raised as an RFI/RI issue. It is unclear why the State is continuing to question RFI/RI issues in this document inappropriately.

Resolution

Based on the meetings held on December 8 and December 14, 1994, between DOE, EPA, and CDPHE, subsurface soil PRGs will not be calculated directly. The subsurface soil RAO included in the OU 1 CMS/FS report will be revised as discussed in the response to General Comment # 11.

Comment 14

Inadequate Documentation of Remedial Action Alternative Development and Screening Process -- The Division does not find the documentation and supporting rationale for the development and screening of remedial action alternatives as presented in TM 11 and the draft CMS/FS to be adequate. The Division commented on the development and screening of alternatives in several specific comments to TM 11. The DOE has failed to resolve these comments or address the Division's concerns.

The DOE has on several instances chosen to cite CERCLA guidance as a rationale for not addressing the Division's concerns. This is not adequate. All of the Division's comments must be fully resolved to the Division's satisfaction and integrated into the CMS/FS. The CMS/FS must include a thorough documentation of the remedy development and selection process including appropriate supporting rationale. It is not appropriate to reference the DRAFT TM 11 for this documentation.

Response

The draft TM 11 document was incorporated by reference in the OU 1 CMS/FS report as agreed to by DOE, EPA, and the State during various working meetings. At the request of both regulatory agencies, this was done in order to limit the duplication of material found in the TMs and the CMS/FS report. If desired, the final CMS/FS report will include all of the material originally presented in the TMs, although each document will still be available in the administrative record.

CERCLA guidance has been cited where necessary to justify the amount of detail included in the CMS/FS report and/or to explain how specific concepts are applied in the CMS/FS process. DOE has attempted to satisfactorily address the State's concerns while maintaining the intent of RCRA and CERCLA cleanup guidelines which specify evaluating various criteria to determine both the feasibility and necessity of initiating remedial actions. The State's position to date has been that remedial action is warranted at OU 1 regardless of the results of the detailed analysis of alternatives. DOE fundamentally disagrees with this approach and has therefore cited guidance where necessary to maintain an appropriate and accepted methodology for remedy selection.

Resolution

The revised CMS/FS report will not reference the draft TM 11 document. The report will provide information regarding both RCRA and CERCLA remedy selection processes and will incorporate State comments as appropriate.

Comment 15

Impacts of Decommissioning of the French Drain -- Several of the alternatives presented in this document including the DOE preferred alternative recommend the decommissioning of the french drain. The text in several sections discusses decommissioning the french drain by breaching the drain with a backhoe. It does not appear that the decommissioning of the drain was considered in modeling of contaminant migration down gradient of the drain. Specifically any breach in the drain would become a preferential pathway for transport to Women Creek. Contaminated groundwater collected in the decommissioned drain would essentially be discharging directly to Women Creek as surface water. This pathway must be considered in modeling the impact of decommissioning the drain.

The current modeling assumes that if the french drain were decommissioned contamination would eventually reach Women Creek via continued migration of the contaminant plume down gradient of the drain. The fate of contaminated groundwater collected within the french drain after decommissioning must be considered in modeling the impact of such alternatives.

Additionally the eventual final closure of the french drain raises many issues that have yet to be considered including potential decontamination methods, closure performance standards and potential post closure care requirements for the drain. The Division strongly recommends that the DOE fully consider these issues in evaluating the role of the french drain in remedial alternatives at OU 1.

Response

Decommissioning of the drain was not considered in modeling of contaminant migration downgradient of the drain. As discussed in the response to General Comment #1 this issue was not raised during the various meetings held with both regulatory agencies to discuss the conceptual approach applied to modeling OU 1. Additionally it is unclear 1) how decommissioning of the drain would result in direct discharge to surface water and 2) how the State wishes this pathway to be considered in modeling the impact of decommissioning the drain. DOE therefore requests clarification as to what type of modeling the State is suggesting for the french drain.

The State's comments regarding decontamination methods for the french drain are likewise unclear. DOE is unaware of any regulatory provisions for decontaminating this type of unit for closure performance standards or potential post closure care requirements. DOE requests clarification as to what State requirements are being referenced and how these requirements affect selection of a preferred remedy at OU 1.

Resolution

Resolution of this comment is pending information from the State concerning decontamination requirements, closure performance standards and potential post closure care requirements for the drain.

Comment 16

Role of Institutional and Engineering Controls NCP explains that institutional controls shall not substitute for active response measures as the remedy unless such active measures are determined not to be practicable based on the balancing of trade offs among alternatives (300.430 (a) (1) (iii)). Clearly not the case here. In any event, the use of institutional controls to limit exposure at the site does not alleviate the requirement to meet or waive all ARARs.

Response

DOE agrees with the statement on the use of institutional controls. DOE requests clarification of the State's position given the State's acknowledgment that it has not reviewed the detailed analysis of alternatives and therefore has not examined the analysis of the RCRA and CERCLA evaluation criteria (i.e., trade offs) for each proposed remedial action. DOE also requests that the State specify why institutional controls are not appropriate for OU 1. DOE agrees that the use of institutional controls do not alleviate the requirement to meet or waive all ARARs and does not present this view in the CMS/FS report.

Resolution

This comment does not require resolution.

Comment 17

Regulatory Requirements for IHSS 130 Radioactive Site 800 Area Recent groundwater monitoring data for the three monitoring wells directly down gradient of IHSS 130 (36391 36691 37191) show the presence of hazardous constituents not detected during the Phase III RFI/RI sampling. The data from two of these wells over the time frame utilized in the RFI/RI (1990 to mid 1992) were limited to only a single sampling event. The newer 1993 monitoring data may confirm the HRR report that hazardous waste associated with the OPWL were disposed of at this IHSS and are potentially leaching from this IHSS into the groundwater. As a result the Division is currently reviewing this monitoring well data to determine if IHSS 130 is a potential hazardous waste landfill as well as a radioactive waste landfill. As such the Division requires that remedial action alternatives be developed for this landfill that are protective of human health and the environment and meet all the appropriate regulatory requirements.

Response

DOE disagrees with the assumption that IHSS 130 should be considered a mixed waste landfill. DOE requests that the State provide justification as to why this IHSS falls into this regulatory classification. DOE also disagrees with the State's position given that it is still trying to determine whether IHSS 130 is a potential hazardous waste landfill based on downgradient groundwater data. This comment represents a significant departure from the approach to alternative development presented to the agencies since January of this year. Raising such an issue after preparation of the draft final CMS/FS limits the value of the consultative process that has been occurring to date between DOE and the regulatory agencies. The State has criticized DOE for its approach to negotiating issues; however, it appears as if the discourse which occurs during CMS/FS working meetings is not being considered in written comments. Since January of this year the focus of the OU 1 CMS/FS has been on groundwater remediation. This approach is supported by the RFI/RI report and the BRA in particular. DOE's position is that it is inappropriate to target units for remediation which have not been identified as risk contributors at the site and do not exceed existing ARARs.

Resolution

During the meeting held on December 14, 1994, between DOE, EPA, and CDPHE, the State revised its position that IHSS 130 is considered a mixed waste landfill. The State is currently reviewing its approach to classifying this IHSS.

Comment 18

Use of All Available Data The modeling and analysis of groundwater data in this report must use all available field data. Groundwater monitoring data for the hillside is available from 1987 to the present. Limiting this report to groundwater data from 1990 to mid 1992 is not appropriate. Additionally, there is no mention of the December 1993 soil gas survey conducted at IHSS 119.1. The Division requires that all available field data be used in the Final CMS/FS. It is important to note that the RFI/RI was performed using data gathered at a finite point in time (1990 to mid 1992). Inclusion of any new pertinent data into the development of the final CMS/FS is essential in order to help ensure an accurate CMS/FS. Therefore, as new information is obtained and evaluated, further field work at OU 1 may be required prior to a remedy selection.

Response

DOE believes it is appropriate to use the data set considered in the RFI/RI report for the groundwater model constructed for the OU 1 CMS/FS. Groundwater monitoring data for the hillside is available to the present date and will continue to be available in the future. The data set selected for the model is the most appropriate data set to use given its use in the RFI/RI report, to which results of the model are being compared. However, at the request of both agencies, the groundwater model has been revised to include data through 1994. It is assumed that this data will be sufficient to satisfy this comment.

DOE disagrees with the State's position that as new information is obtained and evaluated, further field work at OU 1 may be required prior to remedy selection. Remedy selection is based on the results of the CMS/FS report, which in turn is based on the results of the RFI/RI report. DOE believes that the State is inappropriately suggesting continued RFI/RI characterization while continuing to request that the CMS/FS be conducted regardless of unresolved characterization issues.

The CMS/FS report will be revised to reference all soil gas surveys. The data was used indirectly in the CMS/FS during conceptualization of remedial action alternatives. The text will be revised to include this information.

Resolution

This comment will be resolved as discussed in the response presented above.

Comment 19

Detailed Analysis of Alternatives As documented in the Division's comments, the DOE has made many fundamental mistakes in the CMS/FS process, including selection of ARARs and PRGs and the development of alternatives. The number and degree of these mistakes have forced the Division to conclude that the underlying basis for the detailed analysis of alternatives and the preferred alternative presented in this draft CMS/FS are fatally flawed and without basis. The Division requires that, after the ARARs, PRGs, development of alternatives and all other underlying errors in this report are corrected, the detailed analysis of alternatives and DOE preferred remedy be reworked.

The detailed analysis of alternatives must include detailed documentation of how the potential remedy will comply with each of the five standards for evaluation of a final corrective measure alternative presented in the RCRA Corrective Action Plan (OSWER Directive 9902.3-2) as well as the nine CERCLA criteria. Specifically, the Division requires the reworked detailed analysis of alternatives to include how the sources of releases will be controlled and to comply with any applicable standards for management of wastes as evaluation criteria.

The Division has not specifically commented on section 4.0 Detailed Analysis of Alternatives of this draft CMS/FS. The Division finds that, based on the number and significance of the unresolved issues, the evaluation of section 4 is not warranted at this time. This should not be construed as concurrence by the Division on anything contained in Section 4 of the draft CMS/FS.

Response

DOE does not agree that mistakes were made in the CMS/FS process at OU 1. Many of the issues raised by the State have failed to point to specific deficiencies in the CMS/FS report and instead are general statements that are not supported by clear examples. In many cases, issues presented are opinions of the State which have not necessarily been identified by the EPA as deficiencies. Several comments received from the State suggest that the document does not include an analysis of the RCRA standards. Because the State did not evaluate the detailed analysis of alternatives where these criteria are evaluated, DOE does not believe these comments are warranted. The table included in the response to General Comment #2 delineates how the RCRA evaluation criteria compare to the CERCLA evaluation criteria, which are included in the detailed analysis of alternatives. The State has suggested in several comments that the RCRA criteria have not been considered. As shown in the table included in the response to General Comment #2, CERCLA and RCRA evaluation criteria are similar and are discussed at length in Section 4.0 of the CMS/FS report.

Resolution

During the meeting held on December 14, 1994, between DOE, EPA, and CDPHE, the State revised its position that the OU 1 CMS/FS report does not contain sufficient information regarding the RCRA CAP evaluation criteria, with the exception that source control measures are not adequately discussed under alternatives that do not attempt to remediate the source of contamination at IHSS 119.1. The revised CMS/FS report will include more a detailed discussion concerning source control measures under each alternative.

Comment 20

Failure to Adequately Consider Risk in Evaluating Alternatives In the CMS/FS document DOE based its decision on whether remediation alternatives protected human health solely on the modeled predictions of the fate and transport of one chemical PCE. They did not discuss CC14, 1,1-DCE, or any other hazardous constituents. This is unacceptable. RAGS Part B states that all chemicals with risks greater than 1×10^{-6} should remain on the list of chemicals of potential concern for that medium (RAGS part B p 16). A remediation decision based on only one chemical does not consider the cumulative risks from all chemicals in a particular media. In this case, the remediation decision does not even consider the risks from CC14 and 1,1-DCE, both of which are more toxic and present in higher concentrations at OU1 than PCE. Moreover, HQs were not even calculated for inhalation exposure (see Tables C-6-4, 5 & 6) because no inhalation RfD was available for PCE.

If DOE had done a toxicity assessment on this chemical, it would have been apparent that there is no evidence that this chemical causes local respiratory tract irritation, so that it would be appropriate to do route-to-route extrapolation on the oral toxicity factor for this chemical. As it is, DOE did not even evaluate the single chemical it assessed in the CMS/FS for noncarcinogenic effects by the inhalation route of exposure.

Response

The revised OU 1 CMS/FS will include each BRA COC in the risk evaluation for each alternative, with the addition of TCE due to its presence in unusually high concentrations at OU 1. Results from the groundwater model will be examined for each of these COCs and will be incorporated in the appropriate residual risk discussions.

The residual risk for the residential receptor will be documented consistent with the methodology presented in Appendix C. An inhalation reference dose for PCE was not available in IRIS, HEAST, or ECAO. The issue of a RfD for PCE will be deferred to ECAO for additional guidance prior to revision of the CMS/FS report.

Resolution

The resolution to this comment is as stated in the response above.

Comment 21

Groundwater Modeling This model is a first attempt to describe a complex system and as such tends to raise as many or more questions than it answers about the conceptualization of the source locations and inclusion of decay products. The concept of a single flow line within a preferential channel may not adequately describe the flow system between the chosen calibration wells. Slumping is an active process on the hillside and may interrupt what appears to be a bedrock low channel. Current top of bedrock information may not be detailed enough to define a single flow path accurately therefore this model represents a theoretical flow path with a gradient similar to flow paths that may exist on the hillside. Only one conceptualization of the source was considered a residual DNAPL located in one cell at the bedrock/alluvium interface. Alternate source conceptualizations such as diffusion into the pore waters of the bedrock between fractures were not mentioned. The model shows a fair amount of contaminant moving through the bedrock portion of the model so a source within bedrock could be important. Discussion of the choices made in the model conceptualization is an important element in model documentation.

Contaminant calibrations were apparently performed with less than the full suite of available data and not all contaminants in the PCE decay chain were considered. The source and location of each succeeding contaminant becomes dispersed from the transport of its parent product. Such complex linkage of contaminant models becomes too difficult for a transport model dealing with one product at a time. Recognition of this complexity would indicate this model is not conservative.

The English/Metric conflict is not yet resolved in this country. Data in this report is presented in metric units but the model is run in English units and the conversions are not presented. The best option seems to be to present both to facilitate review of the model.

Response

Specific issues in this comment are addressed in the following bullets.

The concept of a single flow line within a preferential channel is based on the hydrogeologic conditions and hydrogeologic conceptual model presented in the RFI/RI report and on fundamental techniques for developing and applying a numerical model. Data from the RFI/RI report reveal limited saturated conditions at OU 1 indicating that flow directions are restricted laterally. The data also indicate that flow is down the hillside consistent with porous media flow and typical hillslope hydrology. The alignment of the modeled flowpath corresponds to the suspected source area beneath IHSS 119 1 and the groundwater flow direction coincident with the bedrock channel consistent with the Phase III RFI/RI. Therefore the model represents the most credible flowpath from IHSS 119 1 to Woman Creek. As such the modeled flowpath is the shortest flowpath in terms of distance and travel time. Other flowpaths would represent longer less conservative flowpaths.

With regard to slumping the interruption referred to in the comment may have little to no effect on groundwater flow direction and magnitude. The geologic cross section produced as part of the Phase III RFI/RI from geologic mapping during the construction of the french drain does not indicate that discontinuities caused by mass movement of colluvium interrupt the bedrock channel which is represented in the model (refer to Volume IV Appendix A of the Phase III RFI/RI figure showing the vertical section of the french drain from station 16+00 to 16+50). The section actually shows the shear plane as conforming with the bedrock channel (in the section the shear plane is also referred to as a potential shear plane and a discontinuous shear plane).

The source represented in the model is that presented in the Phase III RFI/RI as the most credible based on data collected during the RFI/RI. Since the model over estimates all COC concentrations, larger sources (in terms of size) due to spreading caused by decay, or alternate sources are accounted for indirectly by the model. Consider also the possibility of three sources for groundwater contamination: a source above the water table, a source at the bedrock/colluvium interface, and a source in the bedrock. For a source above the water table, the contaminant could not dissolve freely into groundwater. A constant source at the bedrock/colluvium interface could dissolve indefinitely into groundwater. A source in the bedrock could also dissolve into groundwater but would migrate at a slower rate than the source at the bedrock/colluvium interface. Thus, a constant source at the bedrock/colluvium interface represents a conservative scenario. Diffusion as a release mechanism would result in much smaller releases of COCs because it typically occurs at rates much lower than groundwater flow. Further discussion of conservatism and sources is contained on responses to specific comments.

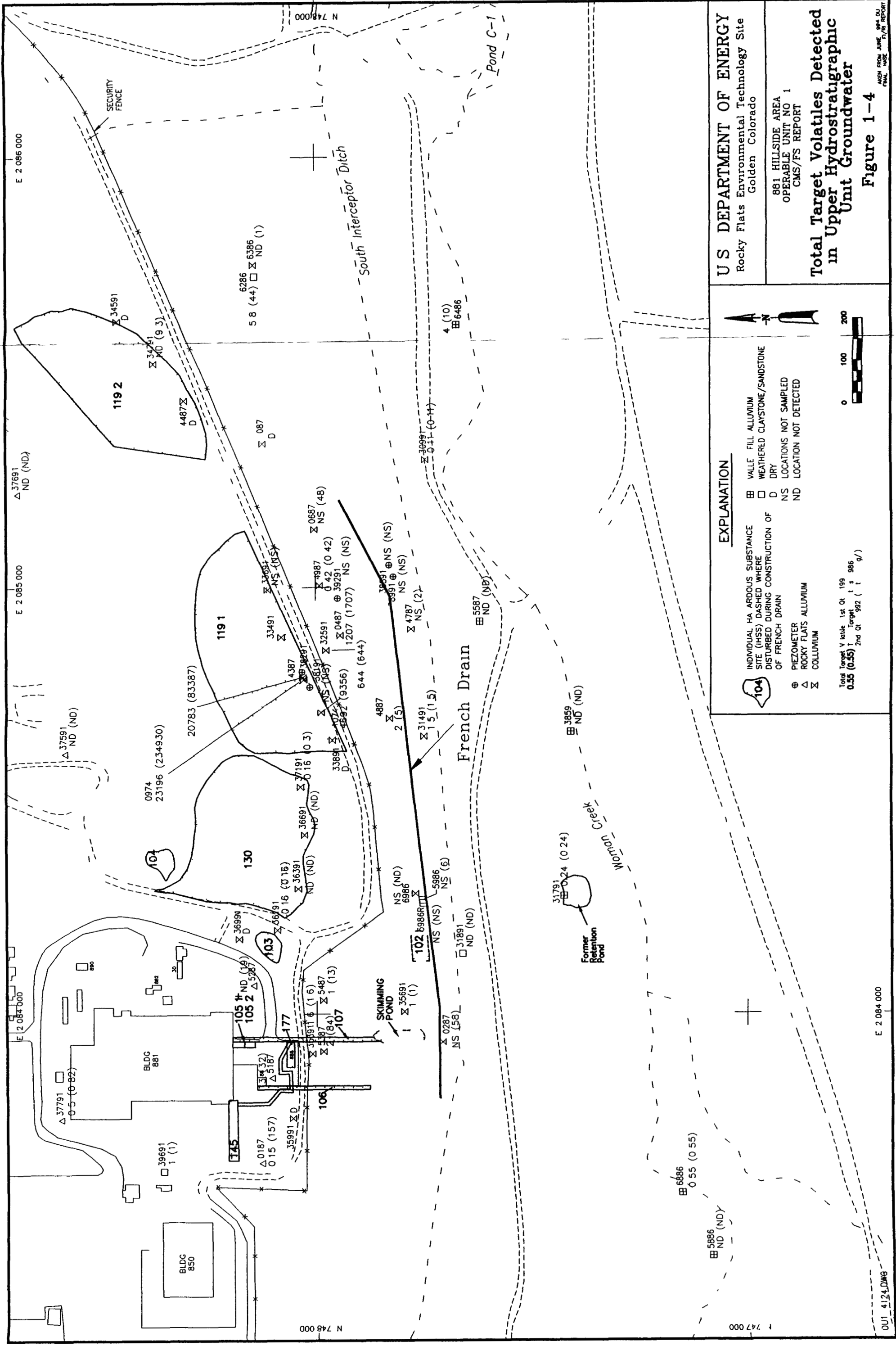
Movement of a solute in bedrock does not indicate source in bedrock. No data gap with regard to bedrock was identified in the Phase III RFI/RI report. Therefore, no bedrock source was simulated in the modeling.

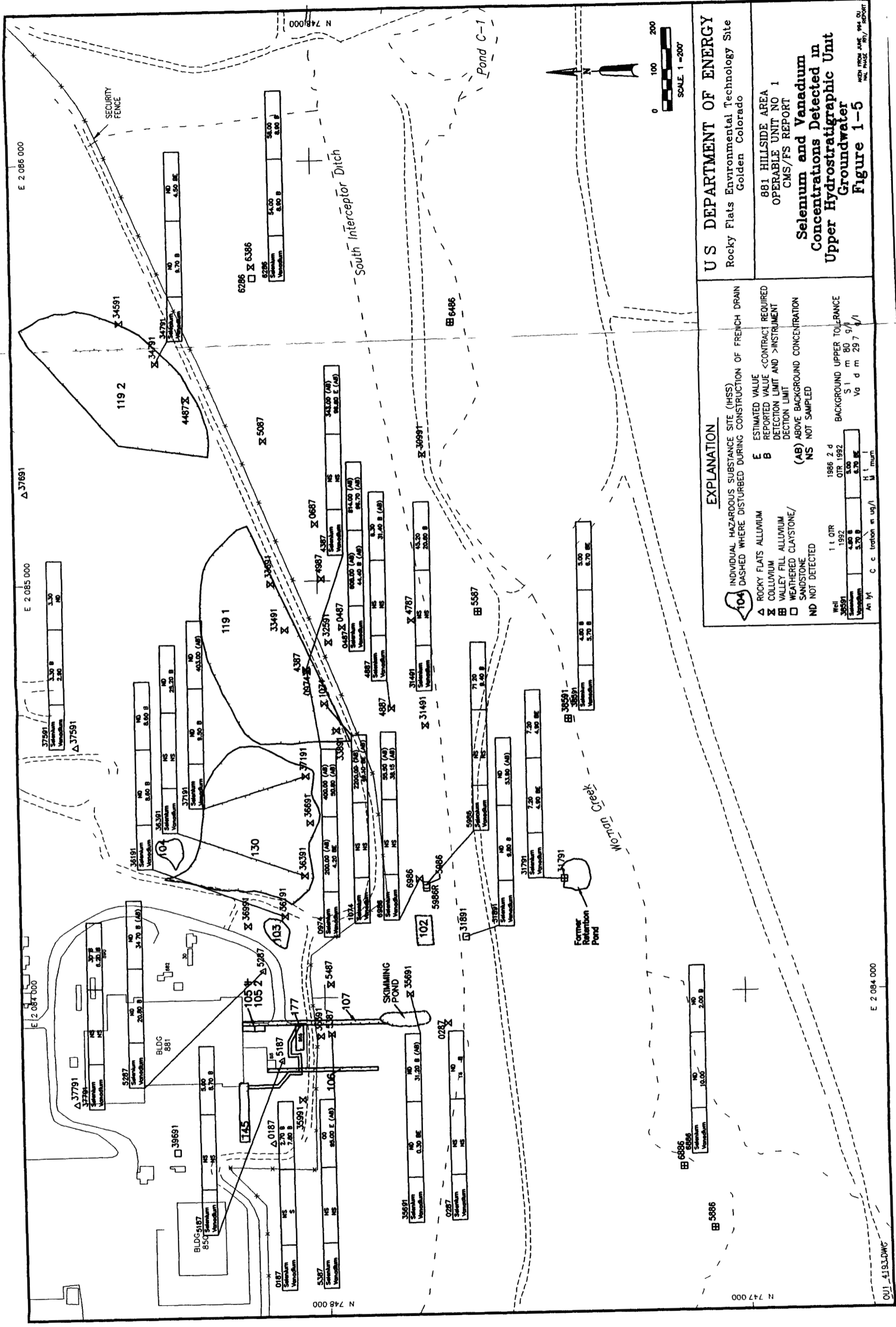
With regard to the issue of conservatism, the model is conservative in two aspects. The simulated groundwater flow is conservative because the model always assumes flow occurs, whereas there are many areas and times of no flow (or low flow) due to dry conditions. The overall hydraulic gradients and therefore Darcian velocities are comparable to those observed at the site. Model predictions are conservative because they consistently over predict COC concentrations. TCE has been included as a COC in the model predictions.

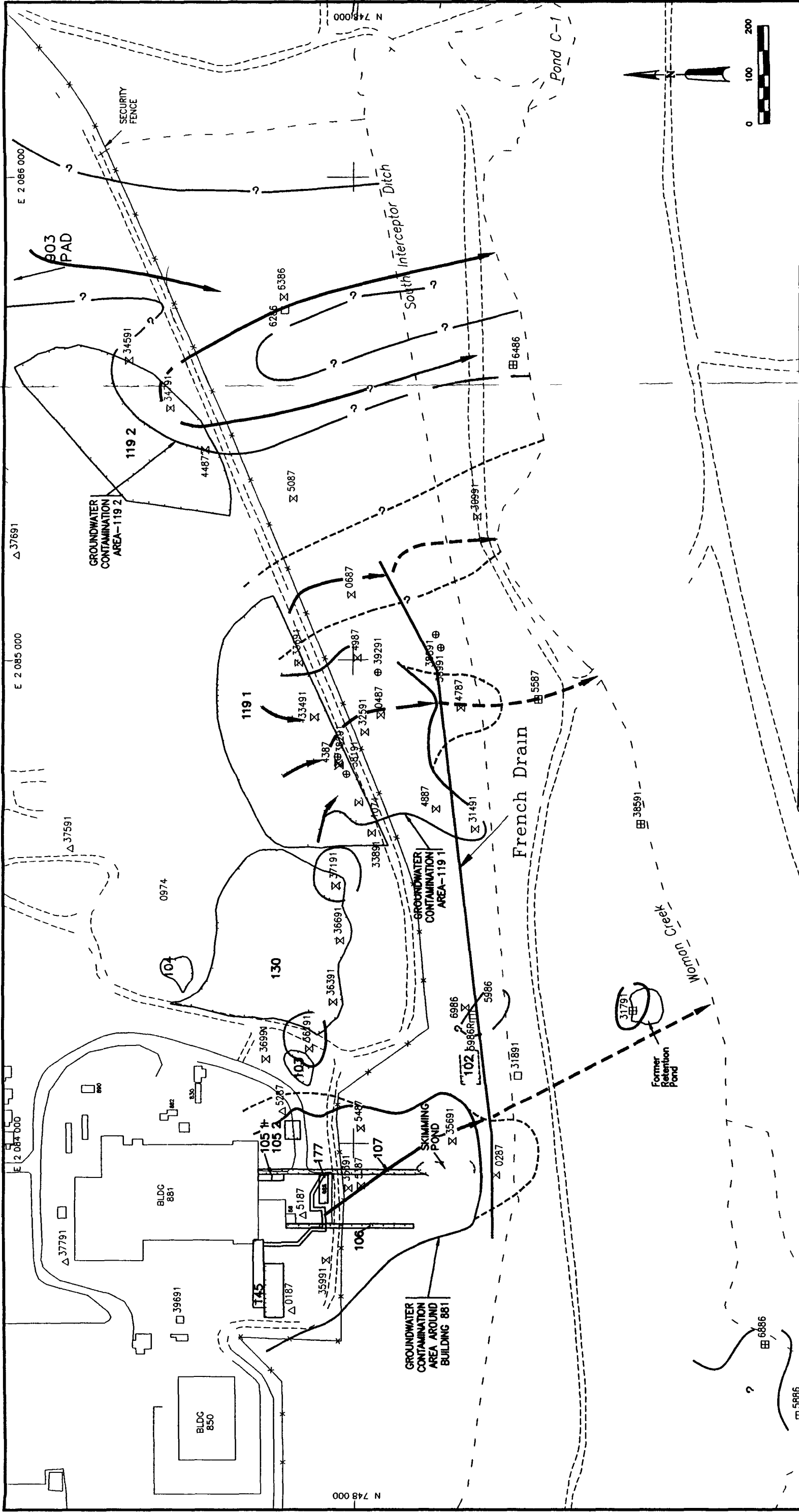
The COCs modeled are consistent with the COCs identified in the Phase III RFI/RI baseline risk assessment and discussed with the agencies on May 23, 1994. This meeting included DOE's explanation of exactly how the model was to be constructed. All parties participated in the discussion. The model was developed in accordance with these discussions as well as with the active participation of CDPHE and EPA representatives during the various informal working meetings that occurred during the modeling process. The function of the model in the FS is to provide a predictive tool to facilitate the selection of a remedial alternative.

Resolution

The resolution of the topics covered in this comment is discussed in more detail in the response and resolution of specific comments.







GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
N Action	N ne	Not ppl bl	Req ured for on deration by NCP	P lly appl c bl as mpari o g ther GRA
			R tr n s prese and future e and/ p rchase f land n ludes ac ns uch as zo g nd deed restrn on	P ally applicabl f co trolling e f land whi h m y be co am r ted
In u onal Control	A cess R trn on	Legal Restr n o s n Land Use	Gra ty dr n illec sy tem whi h sed to red ec gro dwa er fl w and/ r collec for treatm	Pot lly appl ble un l des po b lity f modifying ex g fr h b drain y tem for se d ng reme d on
			Gro olumn are injected erti ally to th so l m lose pro imity f each other form an unperm abl wall	W ld contrib te dditional con nm bec se f ex ng low hydra h cond vity
Containm	Horzo tal S bsurface Flow Co trol	S bsurf ce Drain	A soil/bentonite or cemen grou wall formed by backfilling tre bed area has l wer permeab lity than so ls	Not impl mentable bec use f hills de tab lity cerns tre hu g may lead to sl mp ng f so ls
			S el form which are dr n en to th ground and joined to form barrier wh h s impermeable to groundwater	Very d ff ul to implement d to pro nm y f bedrock w d ly used or accepted lean ps
Vertical S bsurface Flow Co trol	Grou Injection	Slurry Walls	A section f ground frozen to red ce is permeability thus limiting the mobility of co tanunants through the area	O ly ppl abl as short term m asure to control th migma f contaminants through an area
			Grou njected in horizontal pattern be ath urfac so ls to limi ertical migration f VOCs from grou dwater	Not pplcabl for remediation f VOCs in gro dwater fractured bedrock
Remo al	Ex a on	Block Displacement	Inno au se of grout forms perimeter barrier around waste whil displacing waste pward to block pathway	N ppl ble for control f VOCs th res l from lutiliza on f groundwater contaminants no for in fractured bedrock
			Tract /wheel m unted ehicles commonly used or m larg amounts f soil an operate an d ph	Pot ally applicabl for ca t f surface and bsurf so ls
Dispos l	D at Control	Dus S ppres an	Vanou synth tic and tural compo ds wh h are prayed on urfac soil to reduce fugi dus mus s (g water)	P ten lly applicabl red ce d m ssio during emedi of operabl nu
			Ligh easily construct ed tructures sed duri g remedia on that provid protec on from th ffects f wind and rain	Not feas ble because f areal exte f con am so and not cons d ed necessary for l w l f containi an
On S Disposal	On S Disposal	Engineered On S te Disposal Facility	On disposal facility designed o contain e- pec f c waste for ngl operabl nu or for th ure te	Pote ally applicable for torag f niami d so l re duals which res l from the treatme f so ls
			Existing fac lity whi h permu ed to accept perabl pec f c waste or remedial ac on waste treatm res d als	P te u lly applicable for orag f co am ed ils re d als which res l from the treatme f so ls
Off S te Dispos l	Off S te Dispos l	Permi ted Off S te Disposal Facility		

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
In Situ Treatment	Biological	Bioremediation	Destroy organics through microbial degradation on site	Feasibility limited by rate of degradation and diffusion of oxygen
		Chemical	Breakdown of VOCs by chemicals which are typically introduced into the subsurface	Difficult to apply because of environmental impacts and potential for secondary contamination
	Physical	Soil Flushing	Aqueous fluid is forced through soil to dislodge contaminants	Potentially applicable for emulsions and low molecular weight compounds
		Vitrification	Electrical soil heating process that destroys most organic and inorganic contaminants	Applicable for low molecular weight organic compounds
		RF/Ohmic Heating	Radio frequency or Ohmic energy applied to soil to destroy organic and inorganic contaminants	Potentially applicable for low molecular weight organic compounds
		Vapor Extraction	Removal of volatile organic compounds from soil by drawing them into a vacuum	Potentially applicable for low molecular weight organic compounds
	Ex Situ Treatment	Off-Gas/Steam Stripping with Mechanical Mixing	Removal of volatile organic compounds from soil by drawing them into a vacuum	Potentially applicable for low molecular weight organic compounds
		Bioremediation	Destroy organics through microbial degradation	Potentially applicable for treating extracted soils
		Land Application	Application of thin layer of waste or an area to promote natural biodegradation	Potentially applicable for treating extracted soils
		Ultra-violet Photolysis w/ Chemical Oxidation	Removal of organic compounds from soil by mass transfer to an organic solvent which then collects and treats	Potentially applicable for treating extracted soils
	Chemical	Solvent Extraction	Removal of organic compounds from soil by mass transfer to an organic solvent which then collects and treats	Potentially applicable for treating extracted soils
		Soil Washing	Removal of organic compounds from soil by mass transfer to an organic solvent which then collects and treats	Potentially applicable for treating extracted soils
	Physical	Slab Lifting / Solidification / Encapsulation	Removal of organic compounds from soil by mass transfer to an organic solvent which then collects and treats	Potentially applicable for treating extracted soils
		Thermal Desorption	Removal of organic compounds from soil by mass transfer to an organic solvent which then collects and treats	Potentially applicable for treating extracted soils
	Thermal	Vitrification	Removal of organic compounds from soil by mass transfer to an organic solvent which then collects and treats	Potentially applicable for treating extracted soils
	US DEPARTMENT OF ENERGY Rocky Flats Environmental Technology Site Gold Circle			
	881 HILLSIDE AREA OPERABLE UNIT NO. 1			
	Initial Screening of Technologies and Process Options for Subsurface Soils			
	FIGURE 2.3 (Continued)			

Double lines surrounding process option or technology denote options that were screened out from further consideration on the basis of technical implementability, applicability, or feasibility

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
<div></div>	<div> <div>N A t ion</div> <div>N e</div> <div>N ppli bl</div> </div> <div>M nitoring</div> <div>Gro ndwa er M nitoring</div>	<div> <div>Leg l Restr s W ll Plac m n</div> <div>Access Restr ons</div> <div>Leg l Restr on Land Use</div> </div>	<p>Req ed for on d ra on by th N t io l O l d Hazard Substances Con g cy Pl</p> <p>Mon o ng f grou dwate n operabl dun g and after med ion or as part f an m tu on l on l period as oc ed w th N A al m</p> <p>Perm restri ion presen and f repl m f pote l gro ndw ter extra on wells</p> <p>Restri ion presen and future use and/or purchase f land n l des action uch as zoning and deed restri u</p> <p>Grav ty dn llec on sy tem which is sed to reduce grou dwate r fl w and/or collec for treatm n</p> <p>Grou columns are injected ertically to th ol in lose pro unity f each other to form an impermeabl wall</p> <p>A soil/be tonite or cem grou wall formed by backfilling treached area has l wer permeab lity than u soils</p> <p>Steel f rms wh ch are dri en into he gro d and j ined to form barrier wh h impermeabl to groundwater</p> <p>A sec f ground frozen to red ce permeab lity thus limiting th m bility f co tamunan thro gh the are</p> <p>Grou njected in horzo tal pattern bene th urfa e soils to limu eru al migra f VOCs from groundwater</p> <p>Inso wate whl displacing waste pwards to block pathw y</p>	<p>P te lly applic bl as bas lun gau wh h th GRAAs/ l mth es an be mpared d n g d t led analy</p> <p>P lly ppli ble for m n ori g e pecu f c gro ndw rcond ns</p> <p>Pot ally ppli abl for roll ng ce grou dw cr sources and/or expo re to COC</p> <p>P lly ppli able for roll ng se fl d flected by o tamunated groundwater zones</p> <p>Poten lly ppli ble incl des pos bility f modifying ex g fre ch draun sy tem for se d ring remed a o</p> <p>Would contribute add onal con ammen bec se f isting l w hydra h conduc vity</p> <p>N t impl m table because f hills d tabil ty co cem trenchu g may lead to lumping f tu so ls</p> <p>Very diff k implemen d to pro m ty f bedrock wid ly sed or accepted n l an ps</p> <p>Only ppli abl as short term m assure to m gra f contaminants through an area</p> <p>Not ppliabl for remedia o f VOC n gro dw ter in frac ued bedrock</p> <p>Not ppliabl for control f VOC th res l from latilz on f groundwater o tamunants f in fra ued bedrock</p>
				<p>US DEPARTMENT OF ENERGY Rocky Flats Enviro m tal Tech logy S t G lden Col rado</p>
				<p>881 HILLSIDE AREA OPERABLE UNIT NO 1</p>
				<p>Initial Scree ing of Technologies and Process Options f Groundwa e</p>
				<p>FIGURE 2-4</p>

Double lines surrounding process option or technology denote options that were screened out from further consideration on the basis of technical implementability, applicability or feasibility

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
<div>Ex Situ Treatment</div>	<div>Bio</div>	<div>Bioaugmentation</div>	<p>Destroy organic substances by microorganisms</p>	<p>Probably applicable for extracting hydrocarbons from groundwater</p>
		<div>Bioremediation</div>	<p>Removal of organic substances by mass transfer</p>	<p>Probably applicable for groundwater VOCs</p>
		<div>Chemical</div>	<p>UV radiation</p>	<p>Probably applicable for destroying groundwater organic compounds</p>
	<div>Physical</div>	<div>Groundwater Extraction</div>	<p>Removal of organic substances by mass transfer</p>	<p>Probably applicable for groundwater VOCs</p>
		<div>Groundwater Extraction</div>	<p>Removal of organic substances by mass transfer</p>	<p>Probably applicable for groundwater VOCs</p>
		<div>Groundwater Extraction</div>	<p>Removal of organic substances by mass transfer</p>	<p>Probably applicable for groundwater VOCs</p>
		<div>Groundwater Extraction</div>	<p>Removal of organic substances by mass transfer</p>	<p>Probably applicable for groundwater VOCs</p>
		<div>Groundwater Extraction</div>	<p>Removal of organic substances by mass transfer</p>	<p>Probably applicable for groundwater VOCs</p>
	<div>Thermal</div>	<div>Incineration</div>	<p>Destroy organic substances through combustion with oxygen</p>	<p>Generally not applicable for liquid treatment</p>
		<div>Plasma Arc Discharge</div>	<p>Pyrolysis of organic substances by high temperature plasma</p>	<p>Probably applicable for destruction of refractory organics</p>
		<div>Catalytic Oxidation</div>	<p>Catalytic oxidation of organic substances</p>	<p>Potentially applicable for treatment of groundwater</p>
		<div>Freeze Drying</div>	<p>Removal of organic substances by freezing and drying</p>	<p>Can produce acid effluent</p>
		<div>Membrane Processes</div>	<p>Application of an osmotic pressure forces contaminants to flow through semi permeable membrane</p>	<p>Not directly applicable for treatment of VOCs</p>
		<div>Electrolysis</div>	<p>Concentration method used to dry effluent from an aqueous waste stream</p>	<p>Not applicable as standard treatment technology</p>
		<div>Freeze Crystallization</div>	<p>Method of removing dissolved organic species by freezing and supporting in trays and crystallizing the solvent</p>	<p>Oxygen is bleached for aqueous waste treatment where organic concentration is above 3-7% by weight</p>
	<div>Chemical</div>	<div>Chemical Oxidation</div>	<p>Application of an oxidant to destroy organic substances</p>	<p>Not directly applicable for treatment of VOCs</p>
		<div>Chemical Reduction</div>	<p>Application of a reducing agent to destroy organic substances</p>	<p>Not directly applicable for treatment of VOCs</p>

Double lined surrounding process option or technology denote options that were screened out from further consideration on the basis of technical implementability applicability or feasibility

US DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site

Gold Circle

881 HILLSIDE AREA
OPERABLE UNIT NO. 1

Initial Screening of Technologies and
Process Options for Groundwater

FIGURE 2-4 (Cont.)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
No Action	None	Not applicable	May not achieve remedial action objectives although required for consideration by NCP	Difficult to implement if public concerns high regarding technology	Very Low Capital Very Low O & M
Institutional Controls	Access Restrictions	Legal Restrictions on Land Use	Effective for control of present and future use of land which is affected by remedial actions	Difficulty in obtaining necessary legal restrictions may reduce implementability	Low Capital Very Low O & M
Containment	Horizontal Subsurface Flow Control	Subsurface Drains	Effective for containing residual DNAPL sources bounded by bedrock layer (e.g. fractures)	Readily implementable to bedrock afterward in redeveloped area	Moderate Capital Low O & M
Removal	Excavation	Loader/Excavator/Dozer	Effective for excavating soils and sludges less than 30 feet deep	Readily implementable using common road building and construction equipment	Low Capital Moderate O & M
		Dust Suppressants	Moderately effective for reducing surface dust generation depending on type of suppressant	Readily implementable although certain suppressants may be considered hazardous	Low Capital Moderate O & M
Disposal	On Site Disposal	Engineered On Site Disposal Facility	Effective in containing treated or residual wastes assuming the facility is designed properly	Difficult to implement because of permit requirements and administrative concerns	Very High Capital High O & M
		Off Site Disposal	Effective in containing treated or residual wastes if proper facility is available	Readily implementable for wastes other than TRU or mixed (radioactive/hazardous)	Moderate Capital Very Low O & M
In Situ Treatment	Biological	Bioremediation	Effective in treating organics but difficult to monitor progress during in situ treatment, may result in residuals which require further treatment	Requires extensive treatability work to determine viability of microbial growth	Moderate Capital Moderate O & M
		Soil Flushing	Effectiveness limited by site hydrology. Difficult to ensure uniform treatment and flushing agent recovery	Difficult to implement due to preference against injecting additional chemicals into the subsurface	Moderate Capital Moderate O & M
		RF/Ohmic Heating	Effective in treating upper soil layers in situ to prevent migration of contaminants	Readily implementable using commonly available agricultural engineering equipment	Low Capital Moderate O & M
	Physical	Vapor Extraction	Effective in removing organics from subsurface soils to carrier gas which may require treatment	Readily implementable although may be limited by low radius of influence	Low Capital Moderate O & M
		Hot Air/Steam Stripping with Mechanical Mixing	Effective in removing organics from soils to carrier gas for treatment	Implementability may be limited by hillside stability and history of slumping	Moderate Capital High O & M

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1

Evaluation of Process Options
for Subsurface Soils

FIGURE 2-5

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
<div>E S tu T atm nt</div>	<div>B ol gcal</div>	<div>B ore med ano</div>	Effectu e n treatu g organ cs but may poss bly esult res dual which equire further treatme t	Req i s e te s e treatab l ty wo k to determ e viab l ty of m cr b al growth	Moderate C p tal Moderate O & M
		<div>Chemical</div>	Eff e u method for destroyi g some organ c compounds depending on UV lamp used in system	Impleme tab l ty w ll depe d o o id to method chose t accompany UV process	H gh Cap tal H gh O & M
	<div>Sol e t E traction</div>		Eff cu n emoving olatile and no ol tile organic compounds from so ls although spe t sol nt will equire treatment or disposal	Moderately d fficult t mpl me t elatu e to th e s tu tre tme t ptu s	H gh Cap tal Moderate O & M
	<div>Phys cal</div>	<div>Soil Washi g</div>	Effective for removal of rganic and organic contaminants several washing agents available	Impleme table technology which s based on commonly used ore mining technologies	H gh Cap tal Moderate O & M
		<div>Thermal</div>	<div>Incineration</div>	Effective in destroying or removing organic contaminants to le els in the low ppm range	Implementable technology which has bee used e tens ely for treating organics
	<div>Thermal Desorption</div>		Effective for removing olatile and semu olatile compounds from soil requires off gas treatment	Implementable technology which has been used e tens ely fo treating organics	H gh Cap tal High O & M
U S DEPARTMENT OF ENERGY Rocky Flats Environmental Technology Site Golden, Colorado					
881 HILLSIDE AREA OPERABLE UNIT NO 1					
Evaluation of Process Options for Subsurface Soils					
FIGURE 2-5 (Cont.)					

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
No Action	None	Not Applicable	May not achieve remedial action objectives although required for consideration by NCP	Difficult to implement if public concern high regarding site conditions	Very Low Capital Very Low O & M
	Monitoring	Groundwater Monitoring	Effective in monitoring site conditions with No Action alternative as an institutional control	Readily implementable depending on remedial alternative selected	Low Capital Low O & M
Institutional Controls	Access Restrictions	Legal Restrictions on Well Placement	Effective for control of present and future access to groundwater	Difficulty in obtaining necessary legal restrictions may reduce implementability	Low Capital Very Low O & M
		Legal Restrictions on Land Use	Effective for control of present and future use of land which is affected by remedial actions	Difficulty in obtaining necessary legal restrictions may reduce implementability	Low Capital Very Low O & M
Containment	Horizontal Surface Flow Control	Surface Drains	Effective in diverting flow of groundwater around targeted areas to limit the mobility of contaminants	May be difficult to implement upgradient of plume due to proximity of buildings	Moderate Capital Low O & M
Removal	Passive Removal	Surface Drains	Effective in collecting groundwater if the system is designed appropriately for site conditions	Modification of existing French drain would be readily implementable if required	Moderate Capital Very Low O & M
	Active Removal	Horizontal and/or Vertical Extraction Wells or Sumps	Effective in diverting collection and recharging groundwater when gradients relatively flat	Readily implementable based on existing site conditions if few wells are involved	Low Capital Low O & M
U S DEPARTMENT OF ENERGY Rocky Flats Environmental Technology Site Golden, Colorado					
881 HILLSIDE AREA OPERABLE UNIT NO 1 Evaluation of Process Options for Groundwater					
FIGURE 2-6					

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
In Situ Treatment	Biological	Bioremediation	Effective in treating organics but difficult to monitor progress during in situ treatment may result in residuals which require further treatment	Requires the selection of a suitable microorganism for existing site specific conditions	Moderate Capital Moderate O & M
	Physical	Vapor Extraction	Moderately effective in removing VOCs from saturated soils although limited by nature of contamination	Would require the use of extraction wells to temporarily depress the water table	Low Capital Moderate O & M
Ex Situ Treatment	Biological	Bioremediation	Effective in treating organics but may possibly result in residuals which require further treatment	Readily implementable if all contaminants can be degraded under similar conditions	Moderate Capital Moderate O & M
	Chemical	Ultraviolet Photolysis with Chemical Oxidation	Effective and proven method of destroying organic contaminants in extracted groundwater	UV treatment system already exists on site and may be used without significant modification	High Capital High O & M
	Physical	Activated Carbon or Carbonaceous Adsorbents	Effective if used as a final polishing step in a groundwater treatment system	Readily implementable as this is a common technology supported by many vendors	Moderate Capital Moderate O & M
		Air Stripping	Effective in removing VOCs and some SVOCs from extracted groundwater in large volumes	Readily implementable as this is a common technology supported by many vendors	Low Capital Moderate O & M
	Thermal	Plasma Arc Discharge	Effective in destroying organics including refractory halogenated compounds	Treatability studies required to optimize energy levels and treatment times for RFETS	High Capital Moderate O & M
		Catalytic Oxidation	Effective in destroying organics including refractory halogenated compounds	Treatability studies required to determine catalyst, temperature and residence time	High Capital Moderate O & M
US DEPARTMENT OF ENERGY Rocky Flats Environmental Technology Site Golden Colorado					
881 HILLSIDE AREA OPERABLE UNIT NO 1 Evaluation of Process Options for Groundwater					
FIGURE 2-6 (Cont.)					

PROPOSED REMEDIAL ACTION ALTERNATIVES							
GENERAL RESPONSE ACTION	PROCESS OPTION	0	1	2	3	4	5
		No Action	Institutional Controls with the French Drain	Groundwater Pumping and Soil Vapor Extraction	Groundwater Pumping and SVE with Thermal Enhancement	Hot Air Injection with Mechanical Mixing	Soil Excavation with Groundwater Pumping
	AREA ADDRESSED =>	N/A	All IHSSs	IHSS 119 1	IHSS 119 1	IHSS 119 1	IHSS 119 1
No action	Groundwater monitoring	✓	✓	✓	✓	✓	✓
Institutional controls	Legal restrictions on land use		✓				
	Legal restrictions on well placement		✓				
Containment	Subsurface drains (existing French Drain)		✓	✓	✓	✓	✓
	Environmental isolation enclosure (optional)						✓
Removal	Subsurface drains (existing French Drain)		✓	✓	✓	✓	✓
	Horizontal and/or vertical extraction wells or sumps		✓	✓	✓	✓	✓
	Loader/dozer/excavator						✓
Disposal	Permitted off site disposal facility						✓
In situ treatment	RF/ohmic heating				✓		
	Soil vapor extraction			✓	✓		
	Hot air/steam stripping with mechanical mixing					✓	
Ex situ treatment	Ultraviolet photolysis with chemical oxidation		✓	✓	✓	✓	✓

Figure 3 1 Development of Remedial Action Alternatives

Table 4 2
(Continued)

RCRA CAP Standards/ CERCLA Eligibility Criteria	ALTERNATIVE 0 None	ALTERNATIVE 1 Install a Catchment and French Drain	ALTERNATIVE 2 Groundwater Pumping and Solute Extraction	ALTERNATIVE 3 Groundwater Pumping and Solute Extraction	ALTERNATIVE 4 Hot Air Injection with Misting	ALTERNATIVE 5 Soil Excavation with Groundwater Pumping
Reduction of Toxicity Mobility or Volume						
Treatment Processes Used	None	Extracted groundwater treated by UV/peroxide on-exchange and GAC processes	SVE as a proprietary technology for soil remediation. Extracted groundwater treated by UV/peroxide on-exchange and GAC processes	RF heating as an innovative technology. Extracted groundwater treated by UV/peroxide on-exchange and GAC processes	Hot air injection with misting technology. Extracted groundwater treated by UV/peroxide on-exchange and GAC processes	Excavated and treated with thermal desorption technology. Off-gas treated by GAC. Extracted groundwater treated by UV/peroxide on-exchange process and GAC
Amount Destroyed or Treated	None	Small quantities of COCs would be treated due to low groundwater concentrations and extraction rate	Treatment area of 100 ft x 100 ft x 20 ft. SVE may not completely remove COCs due to low overall permeability, low COC concentrations, and uncertain location of DNAPL	Treatment area of 100 ft x 100 ft x 20 ft. Greater quantity of COCs may be removed from soil and treated than for Alternative 2 due to thermal enhancement.	Treatment area of 100 ft x 100 ft x 20 ft. Greater quantity of COCs may be removed from soil than for Alternatives 2 and 3 due to increased soil permeability from mixing debris.	Treatment area of 100 ft x 100 ft x 20 ft. COCs removed by excavation and subsequent soil treatment by thermal desorption. Groundwater removed and treated by Building 891 waste treatment system.
Reduction of Toxicity Mobility or Volume	None	French Drain should reduce mobility and volume of COCs. Toxicity reduced through UV/peroxide GAC and on-exchange processes	SVE and groundwater extraction will reduce volume and mobility of COCs. Toxicity reduced through GAC UV/peroxide and on-exchange processes	Reduction of COC volume and mobility in soil may be slightly more effective than for Alternative 2 due to increased oil saturation. Groundwater COC volume and mobility decreased by extraction. Toxicity reduced through GAC UV/peroxide and on-exchange processes	Reduction of COC volume and mobility in soil may be slightly more effective than for Alternatives 2 and 3 due to increased oil saturation and soil permeability. Groundwater COC volume and mobility decreased by extraction. Toxicity reduced through GAC UV/peroxide and ion-exchange processes	Excavation will reduce COC soil volume and mobility. Dewatering may reduce groundwater mobility and volume. Toxicity will be reduced through GAC UV/peroxide and extraction of the processes
Irrversible Treatment	Natural degradation may be irreversible depending on environment. Reactions may create more toxic daughter compounds from parent compounds	Irrversible contamination removal. However, DNAPL-contaminated soil may continue to act as a source	Irrversible contamination removal. However, DNAPLs in soil may continue to act as source	Irrversible contamination removal. However, DNAPL-contaminated soil may continue to act as source	Irrversible contamination removal. However, DNAPL-contaminated soil may continue to act as source	Irrversible contamination removal. However, DNAPLs are removed
Type and Quantity of Residuals Remaining after Treatment	COC concentration in soil and groundwater remain unchanged except for natural degradation.	Residual concentrations of COCs may remain in subsurface soil and groundwater. Creates wastes from GAC and on-exchange processes in Building 891 waste treatment system	Low concentrations of COCs may remain in soil and groundwater. Generated wastes are GAC from off-gas treatment system and on-exchange generated liquid plus GAC from Building 891 waste treatment system	Low concentrations of COCs may remain in soil and groundwater. Generated wastes are GAC from off-gas treatment system and on-exchange generated liquid plus GAC from Building 891 waste treatment system	Low concentrations of COCs may remain in soil and groundwater. Generated wastes are GAC from off-gas treatment system and on-exchange generated liquid plus GAC from Building 891 waste treatment system	Low concentrations of COCs may remain in groundwater. Generated wastes include GAC and on-exchange generated liquid from Building 891 waste treatment system. GAC from thermal desorption system and treated
Statutory Preference for Treatment	Does not satisfy preference for treatment	Satisfies preference for treatment.	Satisfies preference for treatment.	Satisfies preference for treatment.	Satisfies preference for treatment.	Satisfies preference for treatment
Short-Term Effects						
Community Protection	No short-term risks to the public	No increases in short-term risks to the public	No significant increase in potential risks to the public	No significant increase in potential risks to the public	No significant increase in potential risks to the public	Potential risks to public due to fugitive dust generated during excavation, transportation and storage of soil
Worker Protection	No short-term risks to workers	No increase in short-term risks to workers	Potential risks from exposure to COCs in groundwater or soil above and safety hazards associated with drilling and construction, and operation of RF heating	Potential risks from exposure to COCs in groundwater or soil above and safety hazards associated with drilling and construction, and operation of RF heating	Potential risks from exposure to COCs in groundwater soil vapor and safety hazards associated with operating the mixer	Potential risks from exposure to COCs in groundwater soil above and fugitive dust and safety hazards associated with operating excavation equipment and thermal desorption unit

Table 4 2
(Continued)

RCRA CAP Standards/ CERCLA Evaluation Criteria	ALTERNATIVE 0 N A t	ALTERNATIVE 1 Inst t u nal Cont Is w th Fren h Drain	ALTERNATIVE 2 G ndwater Pump ng nd Soil V po Extracti n	ALTERNATIVE 3 G ndw te Pumping and Soil V po Extracti w th Th m l E h cem t	ALTERNATIVE 4 H t Al Injection w th M h m cal Mixing	ALTERNATIVE 5 Soil E ca t n with G dw t Pumpi g
En ro me tal Impacts	Decommiss o g of the F h Drau may esult decr ased w tland and riparian areas in the sh rt term T ansport model g indicates that pred cted peak on e trau ns h uld remain bel w State and Federal surface water standards at Woman Creek.	En ro mental impacts are mu al Transport model g indicates that pred cted peak conce trau ns sho ld remain bel w State and Federal surface water standard at Woman Creek.	Minor impacts to soil l d g l mited loss of egetatio Decommiss on of Fre ch Drau may es lt short term l of w tlands and riparian areas T ansport modeling ind tes that p dicted peak co centration sho ld remain bel w State and Federal surface water standards at Woman Creek.	M or loss of egetatio l st heat g may aff t bsurface bot in the treame t area Sh rt term loss of wetlands and riparian areas f om F e ch Drau decommiss Tran port modeling ndi tes that predicted peak co central hould remain below State and Federal surface waic standards at Woman Creek.	Loss f getati n S gnif cant mp t o en ironm t in the treatm nt area d t mu ing and tu heati g So l stab l ty may be decr ased Short term loss of w tlands and riparian areas f m F n h Drau decommiss ion. Transport model g d tes that pred cted pe k concentrati should remain below State and Federal surface water standards at Woman Creek	S g f cant e r me tal impact d et ca au and f g t dust Short term loss of wetlands and riparian areas from Fre ch Drau decommiss o T ansport model g indicates that p ed cted peak conce trations sh ld remain bel w State and Federal surface water standards at W man Creek.
Implem tability						
Ab l ty to Construct and Operate	Not appl cable	Access control should not be diff cult to implement nor should operation of Fre ch Drau and water treatment processes be diff cult to contin e	Vendors sho ld be able to help with des gn. Wells must be located ear DNAPL source for effecti e treame t Does not require specialized training to operate	Ve dors sho ld be able to help with des gn. Wells must be located near DNAPL source for effecti e treatment Spec al training may be needed to operated the RF heating	Specialized train ng may be needed to operate the eq ipment May be diff c lt to inst all future wells due to unconsol dated soil	Excavaon can be implemented us ng standard equipment Pote tual rad o ucl de contaminatio n subsurface soils may limit s l disposal options
Ease of Do ng M re Action f Needed	W ll not limit the ab l ty to perform future remed al actions	W ll not limit the ab l ty to perform f ture remed al actions	Will not limit the ab l ty to perform f ture remed al acti ns	Will not limit the ab l ty to perform future remed al actions	W ll ot limit the ability to perform future remedial actions	W ll ot limit the ability to perform future remedial actions
Ab l ty to Monitor Effectiveness	Groundwater monitoring programs should track mo ement of COCs	Groundwater monitoring programs should track mo ement of COC	Groundwater and apor monitoring programs should determine effecti ene s	Groundwater and apor monitoring programs sh uld determine effecti e ss	Groundwater and vapor monitoring programs sh ld determine effecti en ss	Groundwater and apor mon tori g programs should determine effecti e ss Rad olog cal monitoring program w ll determine ease of s l di posal and protect wo kers
Ab l ty to Obtain Permits/Coordination with Agencies	Anticipate local opposi ion	No problems anticipated	No probl ms antuc pated	N problems anticipated.	No probl ms anticipated.	Potential radi nuclide contamination in s bsurface soil may limit soil disposal opt o s
Availability of Services and Capacities	No e req ired	No additional services req ired.	Service readily a ailable System can be des g ed to meet req urements	Services readily a ailable System can be des gned to m et requirements	Should be adly a ailable	Serv ces readily a ailable
Availability of Equipment, Specialists and Material	None req ired	None req ired	Readily a ailable	R adly ailable through specialized endors	Should be ailable altho gh techn l gy s proprietary	R adly a ailabl
Availability of Technologies	N ne req ired	None req ired	Readily a ailable	A ailable b t icchnol gy s cons de ed nno au	Techn l gy p roprietary	Read ly a ailable
Cost						
Pr s nt Worth (1995) Cost	\$1 804 200	\$7 565 400	\$7 046 600	\$7 560 500	\$6 015 100	\$13 269 600

Table D 1
Potential Federal
Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard, Requirement, Criteria or Limitation	Citation	0	1	2	3	4	5
		No Action	Institutional Controls with the French Drain	Groundwater Pumping and Soil Vapor Extraction	Groundwater Pumping and SVE with Thermal Enhancement	Steam Injection with Mechanical Mixing	Soil Excavation and Groundwater Removal with Sump Pumps
Resource Conservation and Recovery Act (RCRA)	42 USC Secs 6901 6987						
A Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR Part 257	NA	NA	A ²	A ²	A ²	A ²
B Hazardous Waste Management Systems General	40 CFR Part 260	R/Y	R/Y	A ² /Y	A ² /Y	A ² /Y	A ² /Y
C Identification and Listing of Hazardous Wastes	40 CFR Part 261	R/Y	R/Y	A ² /Y	A ² /Y	A ² /Y	A ² /Y
D Proposed Definition of Hazardous Waste to Exclude Environmental Media ¹ 58FR48156	40 CFR Parts 260 and 261 Secs 261.4 261.42 and Part 268	C/Y ¹	C/Y ¹	C/Y ¹	C/Y ¹	C/Y ¹	C/Y ¹
E Standards Applicable to Generators of Hazardous Waste	40 CFR Part 262	R/Y	R/Y	A ² /Y	A ² /Y	A ² /Y	A ² /Y
F Releases from Solid Waste Management Units	40 CFR Part 264 Subpart F	R/Y	R/Y	R/Y	R/Y	R/Y	R/Y
G Closure and Post Closure	40 CFR Part 264 Subpart G and Secs 264.600 et seq	R/Y	R/Y	A/Y	A/Y	A/Y	A/Y
H Use and Management of Containers	40 CFR Part 264 Subpart I	NA	NA	A/Y	A/Y	A/Y	A/Y
I Landfills	40 CFR Part 264 Subpart N	NA	NA	NA	NA	NA	NA
J Miscellaneous Units	40 CFR Part 264 Subpart X	NA	NA	R/Y	R/Y	R/Y	R/Y
K Air Emission Standards for Process Vents	40 CFR Secs 264.1032 and 264.1033 Subpart AA	NA	NA	A/Y	A/Y	A/Y	A/Y
L Air Emission Standards for Equipment Leaks	40 CFR Secs 264.1056 and 264.1057 Subpart BB	NA	NA	A/Y	A/Y	A/Y	A/Y
M Proposed Air Emission Standards for Storage Units	40 CFR Sec 264.1083 Subpart CC	NA	NA	C/Y ³	C/Y ³	C/Y ³	C/Y ³
N Temporary Unit	40 CFR Sec 264.553 Subpart S	NA	NA	A/Y	A/Y	A/Y	A/Y

¹ Assumes requirements of 261.42 could be met acceptable risk range 10⁻¹⁰ and less than 1 in 10⁶ and groundwater does not pose human health hazard nor environmental hazard
² Applies to new treatment system
³ May apply if concentration of organics in tank exceeds 500 ppm

Table D 1
Potential Federal
Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard Requirement, Criteria, or Limitation	Citation	0	1	2	3	4	5
		No Action	Institutional Controls with the French Drain	Groundwater Pumping and Soil Vapor Extraction	Groundwater Pumping and SVE with Thermal Enhancement	Steam Injection with Mechanical Mixing	Soil Excavation and Groundwater Removal with Sump Pumps
O Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities	40 CFR Part 265	R/Y	R/Y	R/Y	R/Y	R/Y	R/Y
P Interim Status Standards for Owners and Operators of New Hazardous Waste Land Disposal Facilities	40 CFR Part 267	NA	NA	NA	NA	NA	NA
Q Land Disposal Restrictions	40 CFR Part 268	NA	NA	A/Y	A/Y	A/Y	A/Y
Toxic Substances Control Act	15 USC Secs 2601 2629						
A PCB Requirements	40 CFR Part 761	A/Y	A/Y	A/Y	A/Y	A/Y	A/Y
Clean Water Act	33 USC Secs 1251 1376						
A Discharge of Effluent FFCA CWA 90 1 NPDES Federal Facility Compliance Agreement	40 CFR Sec 125 100 40 CFR Sec 122 41	A/Y	A/Y	A/Y	A/Y	A/Y	A/Y
B Toxic Pollutant Effluent Standards	40 CFR Part 129	NA	A/Y	A/Y	A/Y	A/Y	A/Y
C Discharge of Stormwater	40 CFR Sec 122 21 40 CFR Sec 122 26	A/Y	A/Y	A/Y	A/Y	A/Y	A/Y
Atomic Energy Act	42 USC Secs 2011 et seq						
A Radiation Protection and Radioactive Waste Management	10 CFR Secs 20 1301 and 20 1302 Subpart D and Sec 20 2001 et seq Subpart K	NA	NA	NA	NA	NA	A/Y
B Performance Objectives in Licensing for Land Disposal of Radioactive Waste	10 CFR Part 61 Subpart C	C/Y	C/Y	C/Y	C/Y	C/Y	C/Y

⁴ Applies to residuals of treatment system such as spent carbon, HEPA filters or on change as is

⁵ Considered for impacts to groundwater

Table D 1
Potential Federal
Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard Requirement, Criteria or Limitation	Citation	0	1	2	3	4	5
		No Action	Institutional Controls with the French Drain	Groundwater Pumping and Soil Vapor Extraction	Groundwater Pumping and SVE with Thermal Enhancement	Steam Injection with Mechanical Mixing	Soil Excavation and Groundwater Removal with Sump Pumps
Clean Air Act							
A Prevention of Significant Deterioration Requirements	42 USC Secs 7401 7642 40 CFR Part 52	NA	NA	NA	NA	NA	NA
B National Emission Standards for Hazardous Air Pollutants	40 CFR Part 61	NA	NA	R/Y	R/Y	R/Y	R/Y
Safe Drinking Water Act							
Underground Injection Control Program Class V Wells	40 CFR Secs 146.5 and 146.52 Subpart F	NA	NA	NA	NA	R/Y	NA
DOE Orders							
General Environmental Protection Program	5400.1	C/Y	C/Y	C/Y	C/Y	C/Y	C/Y
Environmental Compliance Issue Coordination	5400.2A	NA	NA	NA	NA	NA	NA
Radiation Protection of the Public and Environment	5400.5	NA	NA	NA	NA	NA	C/Y
Environment Safety and Health Programs for DOE Operations	5480.1B	C/Y	C/Y	C/Y	C/Y	C/Y	C/Y
Radioactive Waste Management	5820.2A	NA	NA	NA	NA	NA	C/Y
Hazardous and Radioactive Mixed Hazardous Waste Management	5480.3	C/Y	C/Y	C/Y	C/Y	C/Y	C/Y
Environmental Protection Safety and Health Protection Standards	5480.4	C/Y	C/Y	C/Y	C/Y	C/Y	C/Y

Endnotes

A= Applicable
R= Relevant and Appropriate
NA= Not an ARAR
C = Considered
Y= in compliance or can be compliance
N= not in compliance /standard exceeded

Table D 2
Potential State
Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives

	0	1	2	3	4	5
Standard Requirement, Criteria, or Limitation	No Action	Institutional Controls with French Drain	Groundwater Pumping and Soil Vapor Extraction	Groundwater Pumping and SVE with Thermal Enhancement	Steam Injection with Mechanical Mixing	Soil Excavation and Groundwater Removal with Sump Pumps
Colorado Hazardous Waste Act and State Hazardous Waste Siting Act						
Hazardous Waste Management Regulations Identification and Listing of Hazardous Waste	R/Y	R/Y	A ¹ /Y	A ¹ /Y	A ¹ /Y	A ¹ /Y
Standards Applicable to Generators of Hazardous Waste	R/Y	R/Y	A ¹ /Y	A ¹ /Y	A ¹ /Y	A ¹ /Y
Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities	R/Y	R/Y	A ¹ /Y	A ¹ /Y	A ¹ /Y	A ¹ /Y
Temporary Units	NA	NA	A/Y	A/Y	A/Y	A/Y
Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities	R/Y	R/Y	R/Y	R/Y	R/Y	R/Y
Interim Status Corrective Action Orders	R/Y	R/Y	R/Y	R/Y	R/Y	A/Y
Land Disposal Restrictions	NA	NA	A/Y	A ² /Y	A ² /Y	A ² /Y
Colorado Solid Waste Disposal Sites and Facilities Act						
Colorado Solid Waste Disposal Sites and Facilities Regulations	NA	NA	A ²	A ²	A ²	A ²
Colorado Water Quality Control Act						
A Effluent Limitations	NA	C/Y	C/Y	C/Y	C/Y	C/Y
B Basic Standards and Methodologies for Surface Water Quality	R/N	R/Y	R/Y	R/Y	R/Y	R/Y
C Classifications and Water Quality Standards for Groundwater and Basic Standards	R/N	R/Y ³	R/Y ³	R/Y ³	R/Y ³	R/Y ³

1 Applies to new treatment system.
2 Applies to residuals of treatment system such as spent carbon, HEPA filter or on-line change
3 Possible exception of TCE based on predicted modeling results

Table D 2
Potential State
Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard Requirement, Criteria or Limitation	Citation	0	1	2	3	4	5
Colorado Air Pollution Prevention Control Act, as amended	CRS 25 7 112						
Colorado Air Pollution Control Regulations Air Pollutant Emission Notice Requirements	CCR 1001 5 Regulation 3 Subpart A	NA	NA	NA	NA	NA	NA
State Construction Permits	5 CCR 1001 5 Regulation 3 Subpart B	NA	NA	NA ⁴	NA ⁴	NA ⁴	NA ⁴
Operating Permit Program	5 CCR 1001 5 Regulation 3 Subpart C	NA	NA	NA ⁴	NA ⁴	NA ⁴	NA ⁴
Control of Emissions Volatile Organic Compound	Regulation 7 General Provisions	NA	NA ⁵	R/Y	R/Y	R/Y	R/Y
Soil Erosion Dust Blowing Act	CRS 35 72 101 et seq	NA	NA	R/Y	R/Y	R/Y	R/Y
Act to Establish Power and Duties of Board of Health Department of Health	CRS § 25 1 107 25 1 108 and 25 11 104	NA	NA	NA	NA	NA	NA
Colorado Rules and Regulations Pertaining to Radiation Control	See below						
A Radioactive Material Other than Source Material	6 CCR 1007 1 1 Part III RH 3 3 1 Schedule A	NA ⁶	NA ⁶	NA ⁶	NA ⁶	NA ⁶	A/Y
B Standards for Protection Against Radiation	6 CCR 1007 1 Part IV RH 4 2 1 4 2 2 3	NA ⁶	NA ⁶	NA ⁶	NA ⁶	NA ⁶	A/Y
Colorado Noise Abatement Statute	CRS 25 12 101 et seq	NA	NA	A/Y	A/Y	A/Y	A/Y
Storage Tank Facility Owner/Operator Guidance Documents	Colorado Department of Health December 1992 ¹	NA	NA	NA	NA	NA	NA
State Engineers Authorities							
Colorado Water Well & Pump Installation Regulations	CRS 37 91 101 112 2CCR402 2	NA	NA	C/Y	C/Y	C/Y	C/Y

⁴ Construction requirements do not apply to treatment alternatives source (without consideration of other sources) although some chemicals could trigger a requirement for an operating permit, substantial requirements are found in Regulation 7 for RACT

⁵ Minimal solid disturbance if each drain remains in place

⁶ Assumes no action that would newly disturb rocks or soil

Table D 3
Potential Federal and State
Location Specific ARARs and TBCs for Proposed Remedial Action Alternatives

		0	1	2	3	4	5
		No Action	Institutional Controls with the French Drain	Groundwater Pumping and Soil Vapor Extraction	Groundwater Pumping and SVE with Thermal Enhancement	Steam Injection with Mechanical Mixing	Soil Excavation and Groundwater Removal with Sump Pumps
Standard, Requirement, Criteria or Limitation	Citation						
Resource Conservation and Recovery Act (RCRA)	42 USC Secs 6901 et seq						
General Facility Standards Location Standard Floodplain	40 CFR Part 264 Subpart B 264 18(b)	NA	NA	NA	NA	NA	NA
Endangered Species Act	16 USC Secs 1531 1544						
Interagency Cooperation Endangered and Threatened Wildlife and Plants	50 CFR Part 402 50 CFR Part 17	NA	NA	NA	NA	NA	NA
National Historic Preservation Act	16 USC Secs 470 et seq 36 CFR Part 800	NA	NA	NA	NA	NA	NA
Protection of Historic and Cultural Properties							
Historic Sites, Buildings, and Antiquities Acts	16 USC Secs 461-467						
National Natural Landmarks Program	36 CFR Part 62	NA	NA	NA	NA	NA	NA
Archaeological Resources Protection Act	16 USC Secs 470aa 11 36 CFR Part 296	NA	NA	NA	NA	NA	NA
Protection of Archaeological Resources Uniform Regulations							
Preservation of American Antiquities Act	16 USC Secs 431 433						
Preservation of American Antiquities	43 CFR Part 3	NA	NA	NA	NA	NA	NA
Executive Orders							
Executive Order on Floodplain Management	Executive Order No 11988						
Compliance with Floodplain/Wetlands Environmental Review Requirements	10 CFR Part 1022	NA	NA	NA	NA	NA	NA
Executive Order on Protection of Wetlands	Executive Order No 11990						
Compliance with Floodplain/Wetlands Environmental Review Requirements	10 CFR Part 1022	A/Y	A/Y	A/Y	A/Y	A/Y	A/Y
State Requirements							
Historical Prehistorical and Archaeological Resources Act	CRS 24-65 1 104 CRS 24-65 1 201 202 and 302	NA	NA	NA	NA	NA	NA
State Register of Historic Places Act	CRS 24-80-401 et seq CRS 24-80 1 101 et seq	NA	NA	NA	NA	NA	NA
Non game Endangered or Threatened Species Conservation Act	CRS 33 2 101 et seq	R/Y	R/Y	R/Y	R/Y	R/Y	R/Y